

**SVEUČILIŠTE U SPLITU**  
**FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE**

# **ZAVRŠNI RAD**

**Nikica Kraljević**

**Split, 2018.**

**SVEUČILIŠTE U SPLITU**  
**FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE**

## **PRORAČUN DRVENE HALE**

**Završni rad**

**Split, 2018.**

***Sažetak:***

Na temelju dobivenih podataka, kao što su lokacija građevine, dimenzija glavnih nosača i karakteristike materijala, potrebno je proračunati drvenu okvirnu halu i karakteristične detalje te izraditi radioničke nacрте. Hala je tlocrtnih dimenzija 26x30 m, te visine 10,85 m.

***Ključne riječi:***

drvo, okvirna konstrukcija, LLD, spojevi

## **Designing of a timber hall**

***Abstract:***

On the basis of initial information (structure location, its geometry and the quality of the material), the main objective of the thesis is to design a timber frame hall and characteristic details and make shop drawings. The hall has floor plan dimensions of 26x30 m and it is 10,85 m high.

***Keywords:***

Timber, frame structure, glulam, connections

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**FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE**

Split, Matice hrvatske 15

STUDIJ: **PREDDIPLOMSKI SVEUČILIŠNI STUDIJ  
GRAĐEVINARSTVA**

KANDIDAT: **Nikica Kraljević**

BROJ INDEKSA: **4347**

KATEDRA: **Katedra za metalne i drvene konstrukcije**

PREDMET: **Osnove drvenih konstrukcija**

**ZADATAK ZA ZAVRŠNI RAD**

Tema: Proračun drvene okvirne hale

Opis zadatka: Proračun drvene okvirne hale na temelju dobivenih informacija o lokaciji građevine i karakteristikama materijala. Zadatak uključuje dimenzioniranje svih elemenata hale i pripadajućih spojeva.

U Splitu, rujan 2018.

Voditelj Završnog rada: doc. dr. sc. Neno Torić

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## 1. Tehnički opis

### 1.1 Opis konstrukcije

Zadana konstrukcija, tlocrtnih dimenzija 26/30 m i visine 10,85 m, nalazi se na području Zagreba i projektirana je za potrebe skladištenja. Krovna ploha je u odnosu na horizontalnu ravninu nagnuta pod kutem  $\alpha = 22^\circ$ . Konstrukcija je zamišljena kao okvirni sustav od 7 jednakih okvira razmaknutih za 5,0 m. Statički sustav okvira je trozglojni okvir ojačan metalnom zategom, a statički sustav sekundarne konstrukcije je prosta greda. Greda je izvedena kao nosač jednostrukog, a stup kao nosač dvostrukog poprečnog presjeka.

Na grede okvira se oslanjaju sekundarni krovni nosači (podrožnice) na međusobnom osnom razmaku od 2,003 (m), a na stupove su oslonjeni sekundarni bočni nosači na razmaku od 2,80 (m).

Stabilizacija hale u smjeru okomitom na glavni nosivi sustav ostvarena je spregovima u krovnim i bočnim ravninama i to u krajnjim poljima (prvom i posljednjem). Kao pokrov koriste se aluminijski sendvič paneli.

Vanjski stupovi konstrukcije su zglobno vezani s temeljom. Greda je upeto vezana za stupove.

### Konstruktivni elementi

#### *Krovna greda*

Proračunom je odabrana jednodijelna greda poprečnog presjeka 200/760 mm.

#### *Stupovi*

Proračunom su odabrani vanjski stupovi dvodijelnog poprečnog presjeka 200/760/200 mm.

#### *Zatega*

Proračunom je odabran čelični poprečni presjek RD20. Zatega je u trećinama pridržana za krovnu gredu elementima poprečnog presjeka RD10, kako bi se spriječio vertikalni progib kada je zatega tlačno opterećena.

#### *Podrožnice*

Proračunom su odabrane podrožnice poprečnog presjeka 120/240 mm.

#### *Sekundarni bočni nosači*

Proračunom su odabrane sekundarni bočni nosači poprečnog presjeka 120/180 mm.

#### *Spregovi*

Kao dijagonale krovnog i bočnog sprega odabrane su čelične šipke RD15.

### ***Zabatni stupovi***

Proračunom su odabrani zabatni stupovi poprečnog presjeka 220/600 mm

## **1.2 O proračunu konstrukcije**

Proračun reznih sila i pomaka konstrukcije proveden je po EUROCODE-u 5 gdje je konstrukcija analizirana na krajnje granično stanje i granično stanje uporabljivosti za različite kombinacije opterećenja.

Proračun je proveden po teoriji prvoga reda pri čemu nisu uzete u obzir početne imperfekcije konstruktivnih elementa.

Opterećenja koja djeluju na konstrukciju su:

- opterećenje vlastitim težinom,
  - opterećenje snijegom,
  - opterećenje vjetrom,
- te njihove kombinacije.

Provedeni su proračuni za 4 različite kombinacije opterećenja, te je konstrukcija dimenzionirana na najnepovoljnije rezne sile.

Proračun i dimenzioniranje izvedeni su u programskom paketu SCIA ENGINEER.

## **1.3 Materijal za izradu konstrukcije**

Glavni okvir konstrukcije, kao i sekundarni nosači, izrađeni su od drva LLD Gl24h. Zatega, njezina pridržanja i spregovi izrađeni su od čelika S235.

### **1.4 Montaža i transport**

Predgotovljeni nosači konstrukcije transportiraju se na gradilište u položaju u kojem će kasnije primiti opterećenje, pazeći da se izbjegnu moguća oštećenja.

Izvedba konstrukcije je montažna. Svi elementi konstrukcije predgotovljeni stižu na gradilište te se međusobno vežu vijcima ili trnovima.

Nakon pripremnih radova i betoniranja temelja, prva faza montaže je montaža stupova. Stupovi se zglobno povezuju s temeljima i pridržavaju se u vertikalnom položaju dok se ne povežu s gredama i učvrste zategom. Tada se prva 2 okvira povezujuu krovnim i bočnim spregovima, čime se dobije stabilna konstrukcija na koju se mogu povezivati preostali elementi.

### **1.5 Primijenjeni propisi**

Proračun i dimenzioniranje svih elemenata drvene i čelične konstrukcije provedeni su u skladu sa EUROCODE 5 i EUROCODE 3, a analiza djelovanja na konstrukciju napravljena je u skladu sa EUROCODE 1.

### **1.6 Antikorozivna zaštita**

Svi dijelovi spojnih sredstava izrađeni od čelika moraju biti zaštićeni od korozije prema odredbama "Pravilnika o tehničkim mjerama i uvjetima za zaštitu čeličnih konstrukcije od korozije". Odabrana je zaštita vrućim pocinčavanjem i zaštitnim premazom. Ukupna debljina zaštitnog sloja je 200 µm.

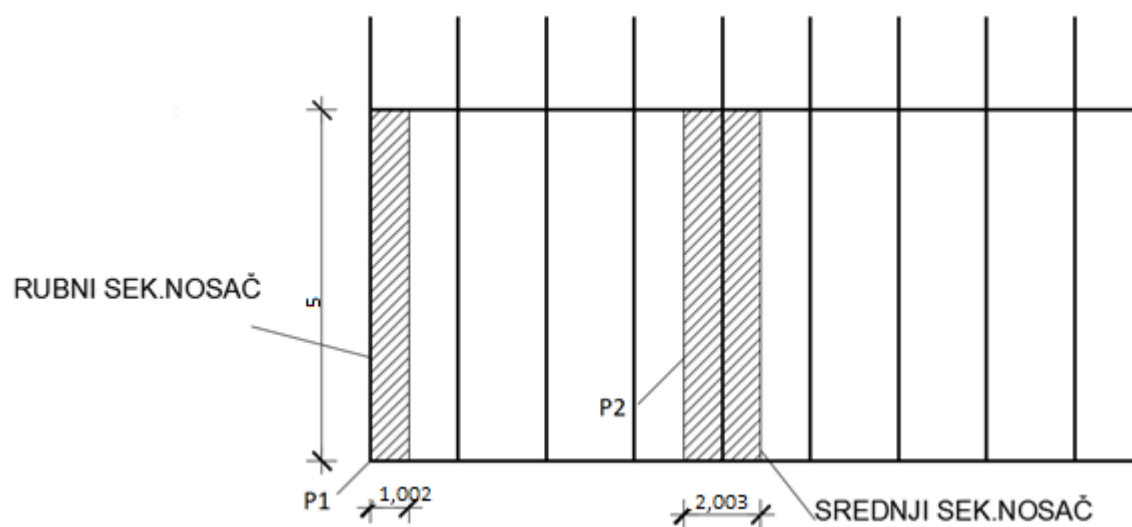
### **1.7 Protupožarna zaštita**

Kako bi se spriječilo prerano zagrijavanje nosivih elemenata konstrukcije prilikom požara, svi takvi elementi moraju se zaštititi posebnim premazima otpornim na visoke temperature. Također je potrebno opremiti objekt uređajima za najavu požara kao i opremom za gašenje.



## 2. Analiza opterećenja

Prikaz raspodjele opterećenja za sekundarne nosače.



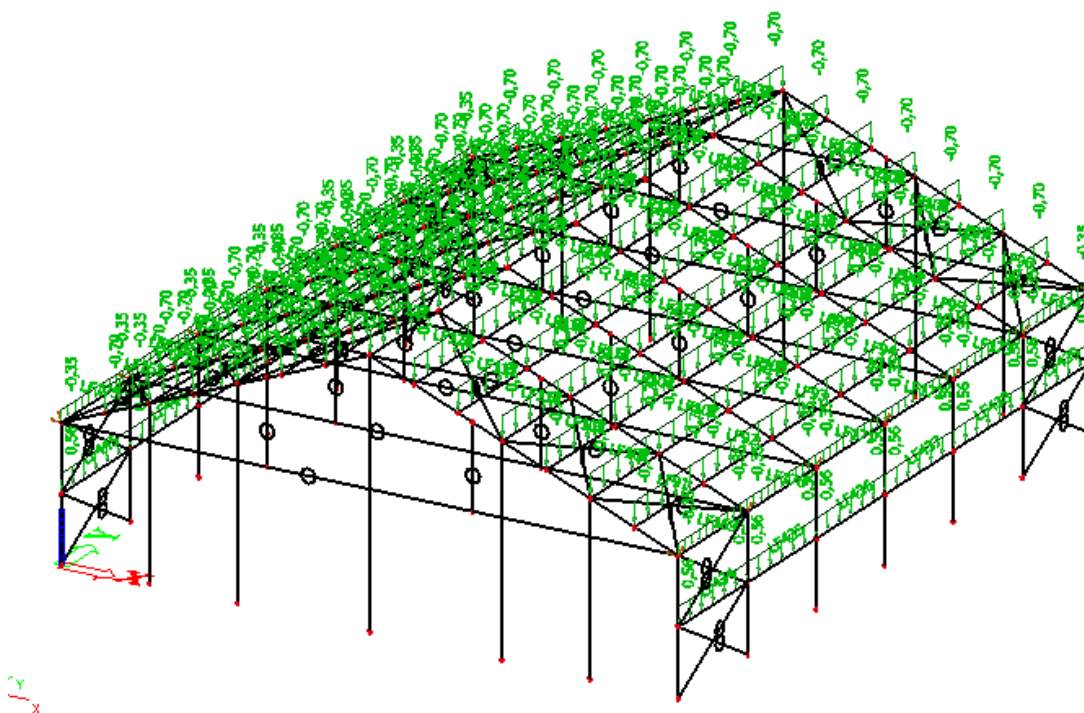
## 2.1 Stalno opterećenje

- pokrov  $g = 0,25 \text{ kN/m}^2$
- instalacije  $g = 0,1 \text{ kN/m}^2$
- vlastita težina –dodana u sklopu računalnog programa

$$\sum g = 0,35 \text{ kN/m}^2$$

DODATNO STALNO OPTEREĆENJE NA KROV $\Delta g$				
NOSAČ	UTJECAJNA POVRŠINA	$\Delta g \text{ (kN/m}^2\text{)}$	L(m)	$\Delta g \text{ (kN/m)}$
RUBNI SEK.NOSAČ	P1	0,35	1,002	0,35
SREDNJI SEK.NOSAČ	P2	0,35	2,003	0,70

DODATNO STALNO OPTEREĆENJE NA BOČNU PODROŽNICU $\Delta g$				
NOSAČ	UTJECAJNA POVRŠINA	$\Delta g \text{ (kN/m}^2\text{)}$	L(m)	$\Delta g \text{ (kN/m)}$
RUBNI SEK.NOSAČ	P1	0,2	2,8	0,56



*Opterećenje modela dodatnim stalnim opterećenjem*

## 2.2 Snijeg

Opterećenje snijegom na krovu

$$s = \mu_1 \cdot C_e \cdot C_t \cdot s_k$$

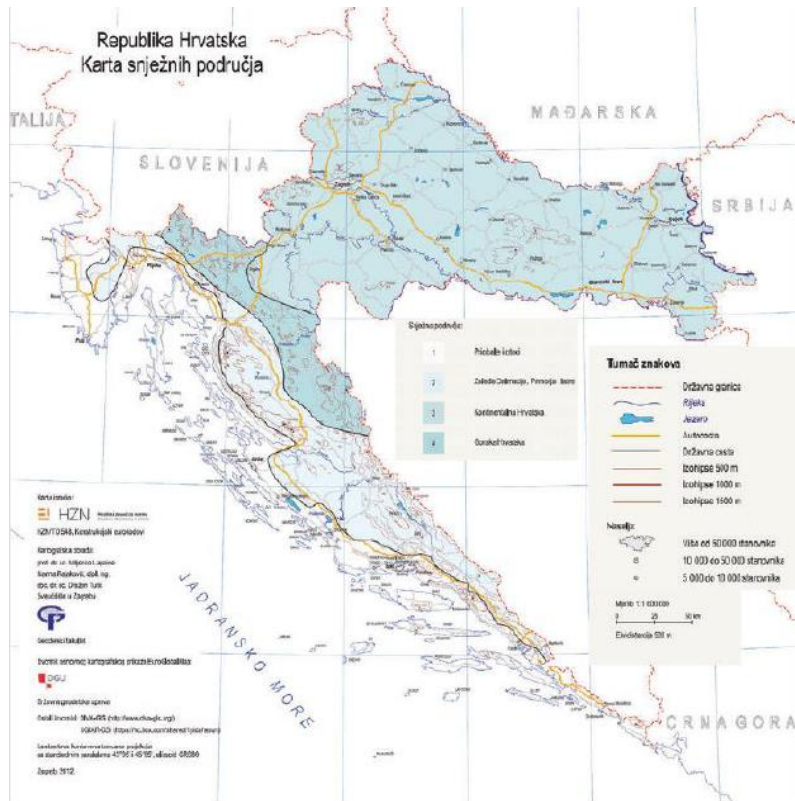
-  $\mu_1$  - koef. oblika za opterećenje snijegom

krov nagiba  $0^\circ \leq \alpha \leq 30^\circ \Rightarrow \mu_1 = 0,8$

-  $s_k$  - karakteristična vrijednost opterećenja na tlu u  $[kN/m^2]$

zona Zagreba, područje 3. (kontinentalna Hrvatska), nadmorska visina do 100 m

$$\Rightarrow s_k = 1,00 \text{ kN/m}^2$$



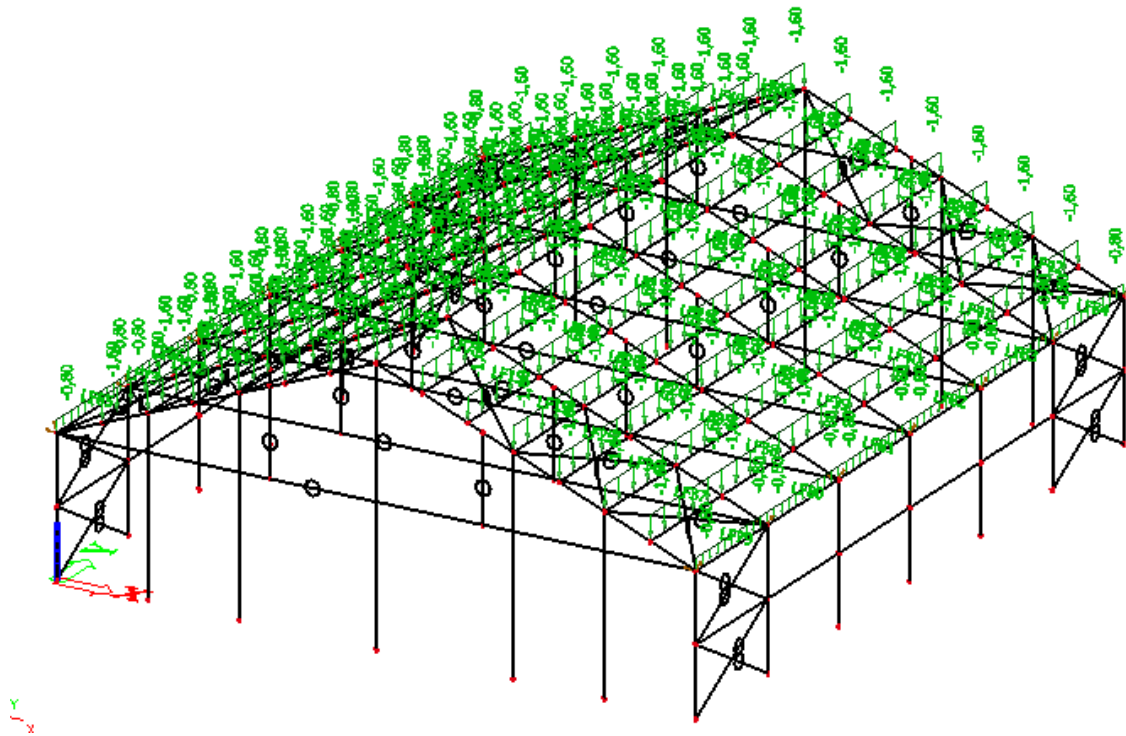
Slika 2.1.. Karta područja za opterećenja snijegom

-  $C_e$  - koef. izloženosti  $\Rightarrow C_e = 1,0$

-  $C_t$  - toplinski koef.  $\Rightarrow C_t = 1,0$

$$\Rightarrow s = 0,8 \cdot 1,0 \cdot 1,0 \cdot 1,0 = 0,8 \text{ [kN/m}^2\text{]}$$

OPTEREĆENJE SNIJEGOM S				
NOSAČ	UTJECAJNA POVRŠINA	S (kN/m <sup>2</sup> )	L(m)	S (kN/m)
RUBNI SEK.NOSAČ	P1	0,8	1,002	0,80
SREDNJI SEK.NOSAČ	P2	0,8	2,003	1,60



*Opterećenje modela snijegom*

### 2.3 Vjetar

- pritisak vjetra na vanjske površine:  $w_e = q_p * c_e(z_e) * c_{pe}$  [kN/m<sup>2</sup>]
- pritisak vjetra na unutarnje površine:  $w_i = q_p * c_e(z_i) * c_{pi}$  [kN/m<sup>2</sup>]

gdje je:

$q_{ref}$  – poredbeni tlak vjetra pri srednjoj brzini vjetra

$C_e(z_e); C_e(z_i)$  – koeficijenti izloženosti koji uzimaju u obzir neravnine terena

$z_e; z_i$  – poredbene visine za lokalni ili unutarnji tlak

$c_{pe}; c_{pi}$  – vanjski i unutarnji koeficijent pritiska



Zemljovid područja opterećenja vjetrom

$$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 [\text{kN/m}^2]$$

gdje je:

$v_b$  – osnovna brzina vjetra

$\rho$  – gustoća zraka ( $\rho = 1,25 \text{ kg/m}^3$ )

Osnovna brzina vjetrova  $v_b$ , dana je izrazom:

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b0}$$

gdje je:

$v_b$  – osnovna brzina vjetra

$c_{dir}$  – koeficijent smjera vjetra (obično uzima vrijednost 1,0)

$c_{season}$  – koeficijent ovisan o godišnjem dobu (obično uzima vrijednost 1,0)

Osnovni pritisak vjetra:

$$v_b = 20,0 \left( \frac{m}{s} \right) \rightarrow$$

očitano za Zagreb

$$C_{dir} = C_{season} = 1,0$$

$$v_b = v_{b,0} \cdot C_{dir} \cdot C_{season} = 20 \cdot 1,0 \cdot 1,0 = 20,0 \left( \frac{m}{s} \right)$$

$$\rho = 1,25 \frac{\text{kg}}{\text{m}^3}$$

$$q_b = \frac{\rho}{2} \cdot v_b^2 = \frac{1,25}{2} \cdot 20,0^2 = 250,0 \left( \frac{N}{\text{m}^2} \right) = 0,25 \left( \frac{kN}{\text{m}^2} \right)$$

Faktor terena  $k_r$  -za kategoriju terena IV :

$$k_r = 0,19 \cdot \left( \frac{z_0}{z_{0,II}} \right)^{0,07} = 0,19 \cdot \left( \frac{1,0}{0,05} \right)^{0,07} = 0,234$$

$$C_{r(z)} = k_r \cdot \ln \left( \frac{z}{z_0} \right) = 0,234 \cdot \ln \left( \frac{10,85}{1,0} \right) = 0,558$$

$$C_{0(z)} = 1,0$$

Srednja brzina vjetra iznad terena:

$$v_{m(11,84)} = v_b \cdot C_{r(z)} \cdot C_{0(z)} = 20 \cdot 1,00 \cdot 0,558 = 11,16 \left( \frac{m}{s} \right)$$

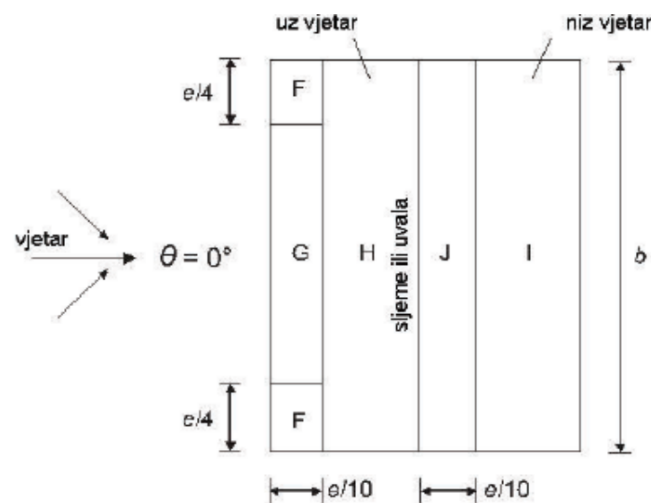
Intezitet turbulencije:

$$I_{v(z)} = \frac{k_I}{C_{0(z)} \cdot \ln \left( \frac{z}{z_0} \right)} = \frac{1}{1 \cdot \ln \left( \frac{10,85}{1,0} \right)} = 0,419$$

Pritisak brzine vjetra pri udaru:

$$q_{p(z)} = [1 + 7 \cdot I_{v(z)}] \cdot 0,5 \cdot \rho \cdot v_m^2 = [1 + 7 \cdot 0,419] \cdot 0,5 \cdot 1,25 \cdot 11,16^2 \cdot 10^{-3} = 0,306 \text{ kN/m}^2$$

**Određivanje pritiska na halu za područja dvostrešnog krova  $\Theta=0$**



Rezultirajuće djelovanje vjetra za dvostrešni krov

$$e = \min \{b_i, 2h\} = \min [30; 2 \cdot 10,85] = 21,7 \text{ m}$$

Koeficijenti vanjskog pritiska na halu s krovom nagiba  $\alpha = 22^\circ$  za područja dvostrešnog krova  $\Theta=0$  dobiveni su interpolacijom između vrijednosti za  $15^\circ$  i  $30^\circ$ .

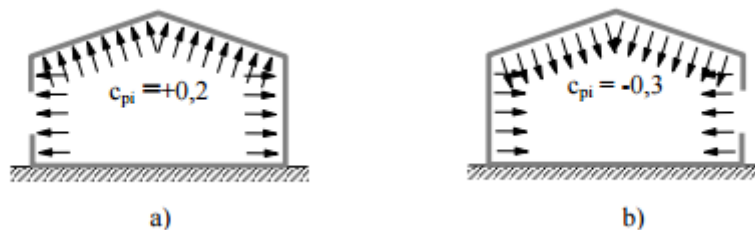
Nagib $\alpha$	Područje za smjer vjetra $\theta = 0^\circ$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

NAPOMENA 1: Pri  $\theta = 0^\circ$  tlak se naglo mijenja između pozitivnih i negativnih vrijednosti na strani uz vjetar oko kuta  $\alpha = -5^\circ$  do  $+45^\circ$ , stoga su navedene pozitivne i negativne vrijednosti. Za takva krova treba uzeti u obzir četiri slučaja gdje su najmanje vrijednosti u svih područja F, G i H kombinirane najvećim ili najmanjim vrijednostima područja I i J. Nije dopušteno miješanje pozitivnih i negativnih vrijednosti na istom pročelju.

NAPOMENA 2: Smije se upotrebljavati linearna interpolacija vrijednosti istog predznaka za međuvrijednosti kutova nagiba istog predznaka. (Ne interpolira se za kutove između  $\alpha = -5^\circ$  i  $\alpha = +5^\circ$  već se upotrebljavaju podaci za ravne krovove iz točke 7.2.3). Vrijednosti 0,0 dane su za potrebe interpolacije.

Tablica 6. Vrijednosti koeficijenata vanjskog pritiska za područja dvostrešnog krova ( $\theta=0^\circ$ )

Za koeficijent unutarnjeg tlaka  $c_{pi}$  uzete su preporučene vrijednosti +0.2 i -0.3.



Koeficijenti unutarnjeg tlaka

Pritisak vjetra na vanjske površine:  $w_e = q_p * c_{pe}$  [kN/m<sup>2</sup>]

Područje	$q_p$ (kN/m <sup>2</sup> )	$c_{pe}$	$W_{e1}$ (kN/m <sup>2</sup> )
F	0,306	-0,514	-0,157
G	0,306	-0,66	-0,202
H	0,306	-0,253	-0,077
I	0,306	-0,4	-0,122
J	0,306	-0,767	-0,235

Područje	$q_p$ (kN/m <sup>2</sup> )	$c_{pi}$	$W_{e2}$ (kN/m <sup>2</sup> )
F	0,306	0,433	0,132
G	0,306	0,433	0,132
H	0,306	0,293	0,09
I	0,306	0,0	0,0
J	0,306	0,0	0,0

Pritisak vjetra na vanjske površine



Pritisak vjetra na unutarnje površine:  $w_i = q_p * c_{pi}$  [kN/m<sup>2</sup>]

Područje	$q_p$ (kN/m <sup>2</sup> )	$c_{pi}$	$W_{i1}$ (kN/m <sup>2</sup> )
F	0,306	0,2	0,061
G	0,306	0,2	0,061
H	0,306	0,2	0,061
I	0,306	0,2	0,061
J	0,306	0,2	0,061

Područje	$q_p$ (kN/m <sup>2</sup> )	$c_{pi}$	$W_{i2}$ (kN/m <sup>2</sup> )
F	0,306	-0,3	-0,092
G	0,306	-0,3	-0,092
H	0,306	-0,3	-0,092
I	0,306	-0,3	-0,092
J	0,306	-0,3	-0,092

*Pritisak vjetra na unutarnje površine*

REZULTIRAJUĆE DJELOVANJE VJETRA (kN/m <sup>2</sup> )				
Područje	Vjetar 1= $W_{e1}+W_{i1}$	Vjetar 2= $W_{e1}+W_{i2}$	Vjetar 3= $W_{e2}+W_{i1}$	Vjetar 4= $W_{e2}+W_{i2}$
F	-0,218	-0,065	0,071	0,224
G	-0,263	-0,11	0,071	0,224
H	-0,138	0,015	0,029	0,182
I	-0,183	-0,03	-0,061	0,092
J	-0,296	-0,143	-0,061	0,092

*Rezultirajuće djelovanje vjetra*

Djelovanje vjetra na krovnu plohu prenosi se na sekundarne nosače koji prenose opterećenje na glavni nosač.

Djelovanje se u modelu nanosi linijski što će biti prikazano u sljedećim proračunima.

Za daljni proračun u obzir će se uzeti vrijednosti za VJETAR 1 koji će se u kombinacijama opterećenja označavati s „vjetar o“ i VJETAR 4 koji će se u kombinacijama opterećenja označavati s „vjetar p“.

Djelovanje vjetra na sekundarne nosače:

REZULTIRAJUĆE DJELOVANJE ZA VJETAR 1 (odižući)			
PODROŽNICA	OPTEREĆENJE (kN/m')	PODROŽNICA	OPTEREĆENJE (kN/m')
1	-0,22	9	-0,30
2	-0,37	10	-0,50
3	-0,28	11	-0,36
4	-0,28	12	-0,36
5	-0,28	13	-0,36
6	-0,28	14	-0,36
7	-0,28	15	-0,36
8	-0,14	16	-0,18

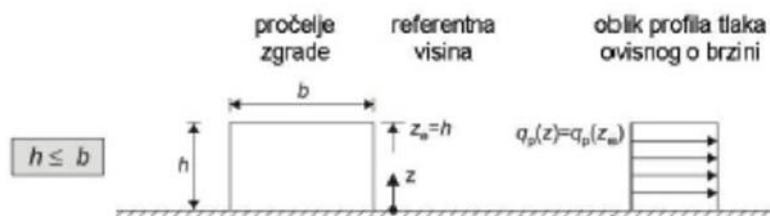
*Prikaz linijskog djelovanja vjetra na sekundarne nosače*



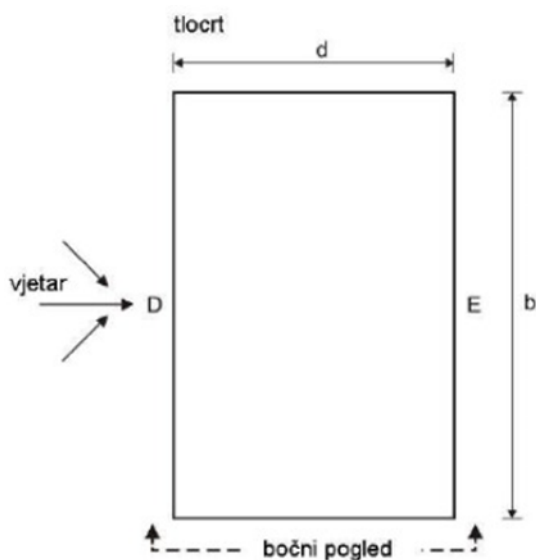
REZULTIRAJUĆE DJELOVANJE ZA VJETAR 4 (pritiskajući)			
PODROŽNICA	OPTEREĆENJE (kN/m')	PODROŽNICA	OPTEREĆENJE (kN/m')
1	0,22	9	0,09
2	0,41	10	0,18
3	0,36	11	0,18
4	0,36	12	0,18
5	0,36	13	0,18
6	0,36	14	0,18
7	0,36	15	0,18
8	0,18	16	0,09

*Prikaz linijskog djelovanja vjetra na sekundarne nosače*

Djelovanje vjetra na zidove konstrukcije:



*Referentna visina i odgovarajuća raspodjela tlaka*



*Djelovanje vjetra na vertikalne zidove*

$$e = \min \{b_i, 2h\} = \min [30; 2 \cdot 10,85 = 21,7] = 21,7 \text{ m}, d = 26,0 \text{ m}$$

Područje	$q_p(\text{kN/m}^2)$	$c_{pe}$	$W_e(\text{kN/m}^2)$
D	0,306	0,733	0,224
E	0,306	-0,367	-0,112

*Pritisak vjetra na vanjske površine*

Područje	$q_p(\text{kN/m}^2)$	$c_{pi}$	$W_{i1}(\text{kN/m}^2)$
D	0,306	0,20	0,061
E	0,306	0,20	0,061

Područje	$q_p(\text{kN/m}^2)$	$c_{pi}$	$W_{i2}(\text{kN/m}^2)$
D	0,306	-0,30	-0,092
E	0,306	-0,30	-0,092

*Pritisak vjetra na unutarnje površine*

REZULTIRAJUĆE DJELOVANJE VJETRA( $\text{kN/m}^2$ )			
Područje	VJETAR 1= $W_e+W_{i1}$	VJETAR 2= $W_e+W_{i2}$	
D	0,163	0,316	
E	-0,173	-0,03	

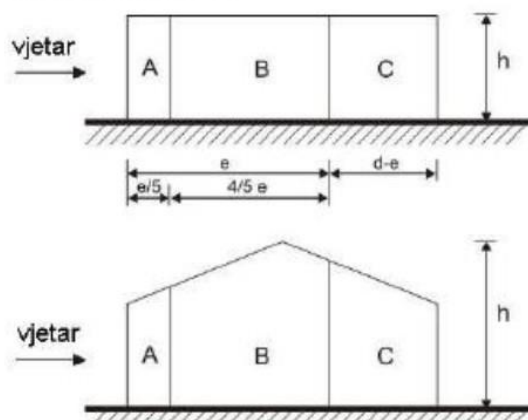
*Prikaz rezultirajućeg djelovanja vjetra (  $V(\text{kN/m}^2)$  )*

REZULTIRAJUĆE DJELOVANJE VJETRA NA BOČNE NOSAČE			
ODIŽUĆI		PRITISKAJUĆI	
1	0,9	1	0,79
2	-0,95	2	-0,11

*Prikaz rezultirajućeg djelovanja vjetra na stupove ( $\text{kN/m}'$ )*

Djelovanje vjetra na zabatni zid :

bočni pogled za  $e < d$



*Prikaz područja djelovanja za zabatne zidove*

Područje	$q_p(\text{kN/m}^2)$	$c_{pe}$	$W_e(\text{kN/m}^2)$
A	0,306	-1,2	-0,367
B	0,306	-0,8	-0,245
C	0,306	-0,5	-0,153

*Prikaz djelovanja na vanjske površine*

Područje	$q_p(\text{kN/m}^2)$	$c_{pi}$	$W_{i1}(\text{kN/m}^2)$
A	0,306	0,2	0,061
B	0,306	0,2	0,061
C	0,306	0,2	0,061
Područje	$q_p(\text{kN/m}^2)$	$c_{pi}$	$W_{i2}(\text{kN/m}^2)$
A	0,306	-0,3	-0,092
B	0,306	-0,3	-0,092
C	0,306	-0,3	-0,092

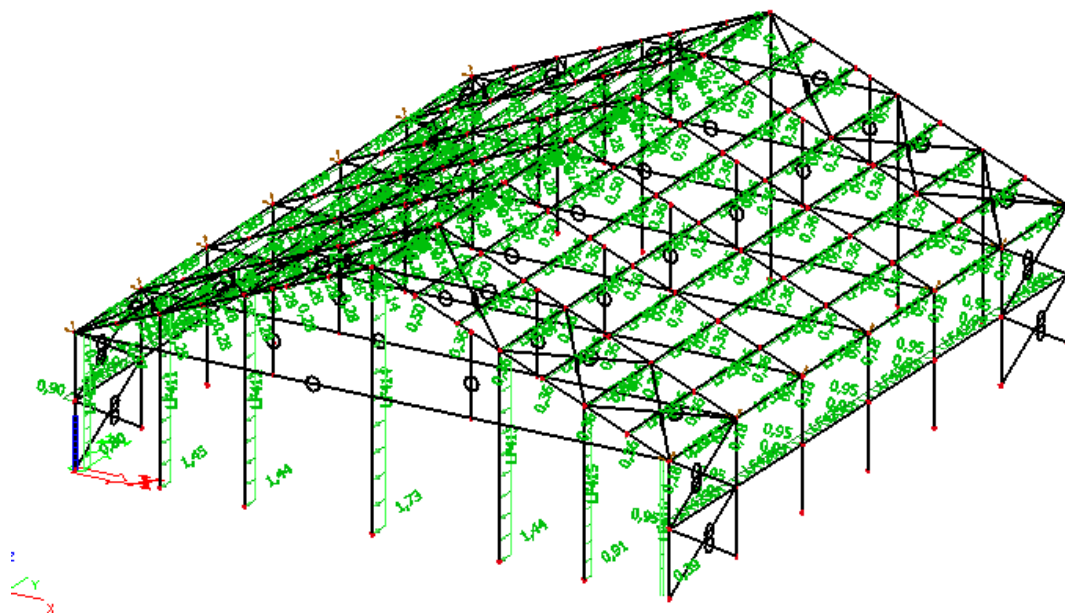
*Prikaz djelovanja na unutarnje površine*

REZULTIRAJUĆE DJELOVANJE VJETRA( $\text{kN/m}^2$ )				
PODRUČJE	VJETAR 1=	$W_e+W_{i1}$	VJETAR 2=	$W_e-W_{i2}$
A	-0,42		-0,27	
B	-0,30		-0,15	
C	-0,21		-0,06	

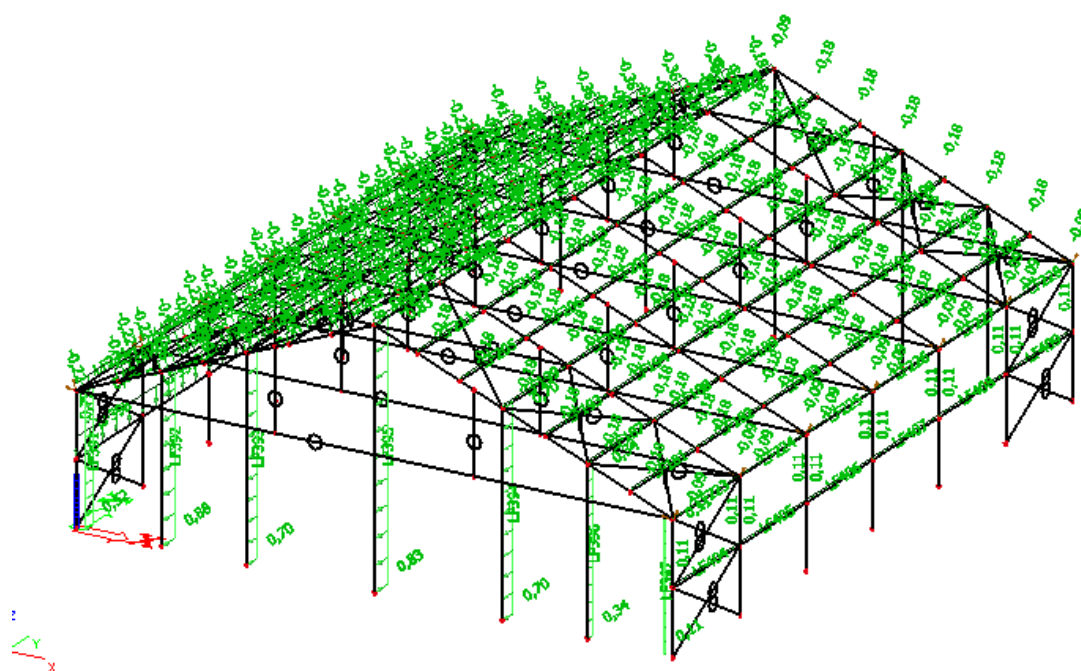
*Prikaz rezultirajućeg djelovanja vjetra*

REZULTIRAJUĆE DJELOVANJE VJETRA NA STUPOVE			
ODIŽUĆI VJETAR ( $\text{kN/m}'$ )		PRITISKAJUĆI VJETAR	
1	-0,9	1	-0,52
2	-1,45	2	-0,88
3	-1,44	3	-0,7
4	-1,73	4	-0,83
5	-1,44	5	-0,70
6	-0,91	6	-0,34
7	-0,39	7	-0,11

*Rezultirajuće djelovanje vjetra na stupove*



*Opterećenje modela odizujućim vjetrom*



*Opterećenje modela pritiskajućim vjetrom*

### 3. Proračun konstrukcije

Proračun konstrukcije izvršen je u programskom paketu Scia Enginner 2014. sa prostornim modelom konstrukcije.

#### 3.1 Kombinacije djelovanja

CO1	Name	CO1
CO2	Description	
CO3	Type	Envelope - ultimate
CO4	<b>Contents of combination</b>	
	tezina [-]	1,35
	stalno [-]	1,35
	snijeg [-]	1,50

CO1	Name	CO2
CO2	Description	
CO3	Type	Envelope - ultimate
CO4	<b>Contents of combination</b>	
	tezina [-]	1,35
	stalno [-]	1,35
	vjetar p [-]	1,50

CO1	Name	CO3
CO2	Description	
CO3	Type	Envelope - ultimate
CO4	<b>Contents of combination</b>	
	tezina [-]	1,00
	stalno [-]	1,00
	vjetar o [-]	1,50

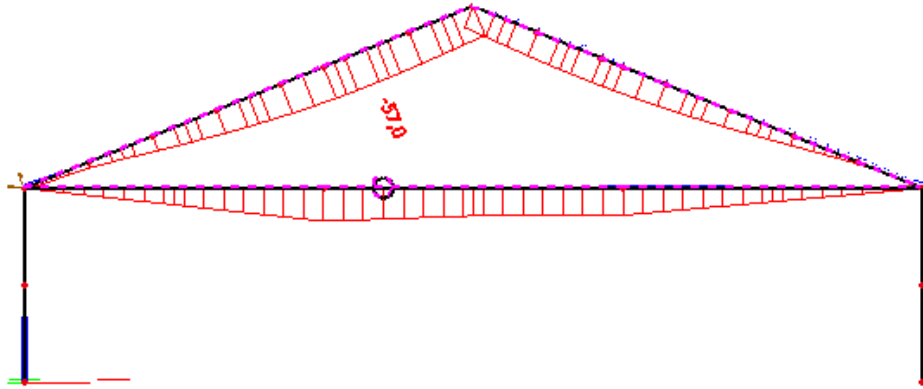
CO1	Name	CO4
CO2	Description	
CO3	Type	Envelope - ultimate
CO4	<b>Contents of combination</b>	
	tezina [-]	1,35
	stalno [-]	1,35
	snijeg [-]	1,35
	vjetar p [-]	1,35

#### 4. Dimenzioniranje elemenata konstrukcije

##### 4.1 Pomaci konstrukcije

Progibi se provjeravaju na krajnje granično stanje.

Vertikalni pomak konstrukcije



Vertikalni pomak

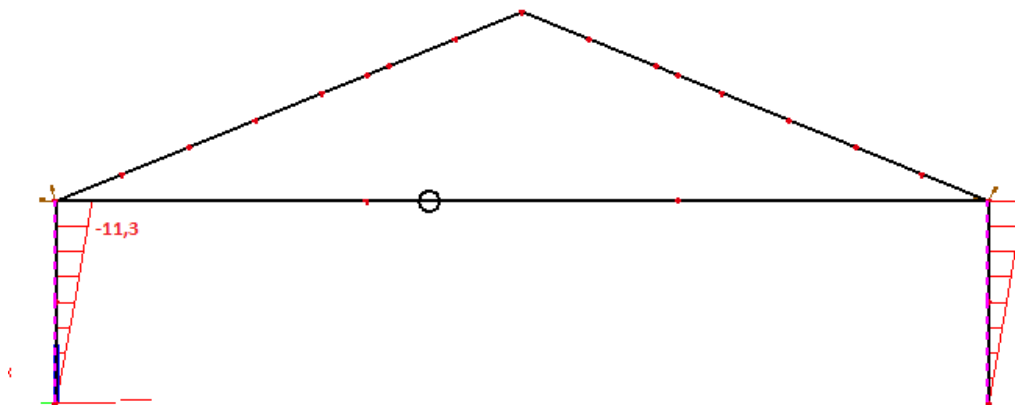
Vertikalni pomak:  $u_z = 57,0 \text{ mm}$

Dopušteni vertikalni pomak:

$$u_{dop} = \frac{l}{300} = \frac{26 \cdot 1000}{300} = 86,67 \text{ mm}$$

$$u_{z,fin} = u_z \cdot (1 + \psi_2 \cdot k_{def}) = 57 < u_{dop}$$

Horizontalni pomak konstrukcije



Horizontalni pomak (opterećenje)

Horizontalni pomak:  $u_x = 11,3 \text{ mm}$

Dopušteni horizontalni pomak :

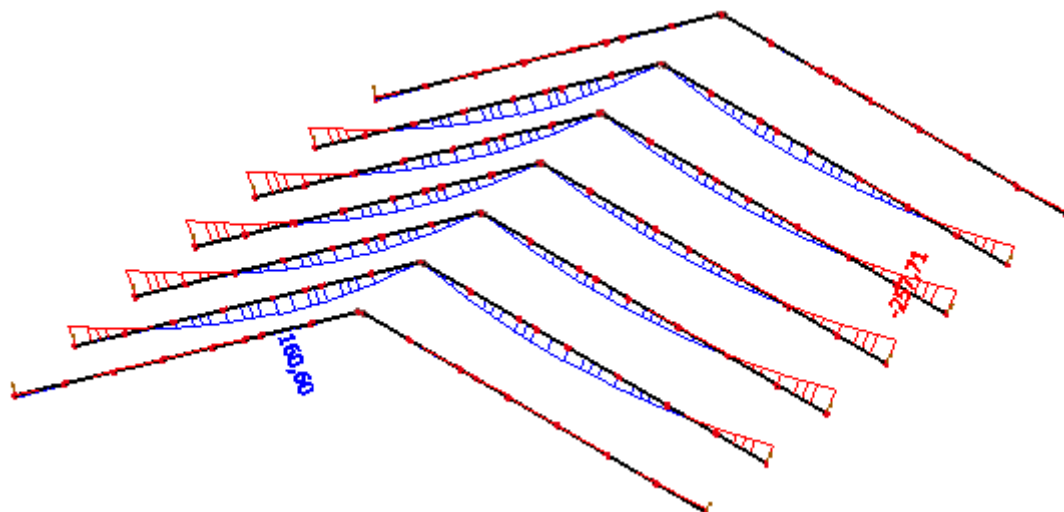
$$u_{dop} = \frac{h}{200} = \frac{5,6 \cdot 1000}{200} = 28,0 \text{ mm}$$

$$u_{x,fin} = u_x \cdot (1 + \psi_2 \cdot k_{def}) = 11,3 < u_{dop}$$

#### 4.2 Dimenzioniranje grede (poz. G1 i G2)

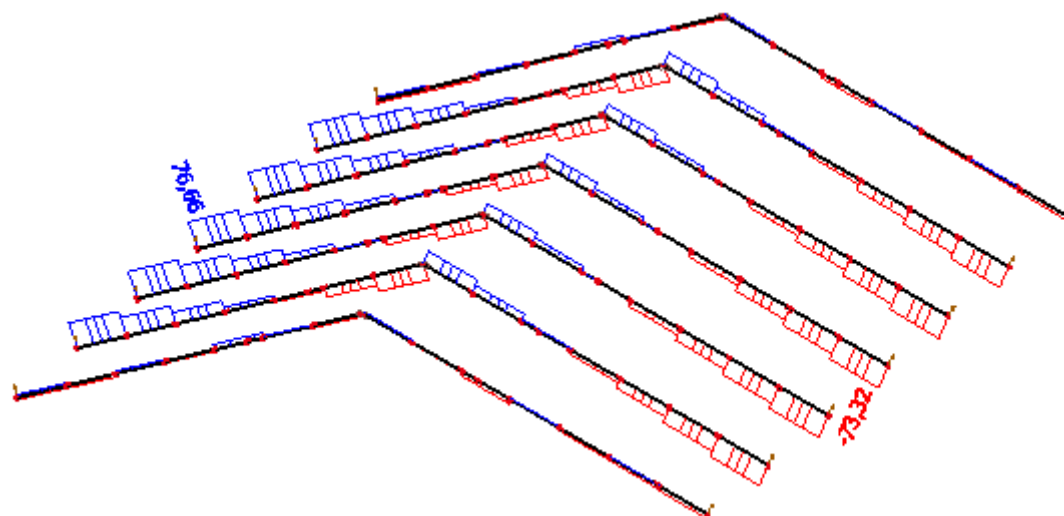
Dimenzioniranje konstrukcijskih elemenata provedeno je softverom Scia Enginner 2014 pomoću modula Timber.

Moment savijanja u gredi (My)



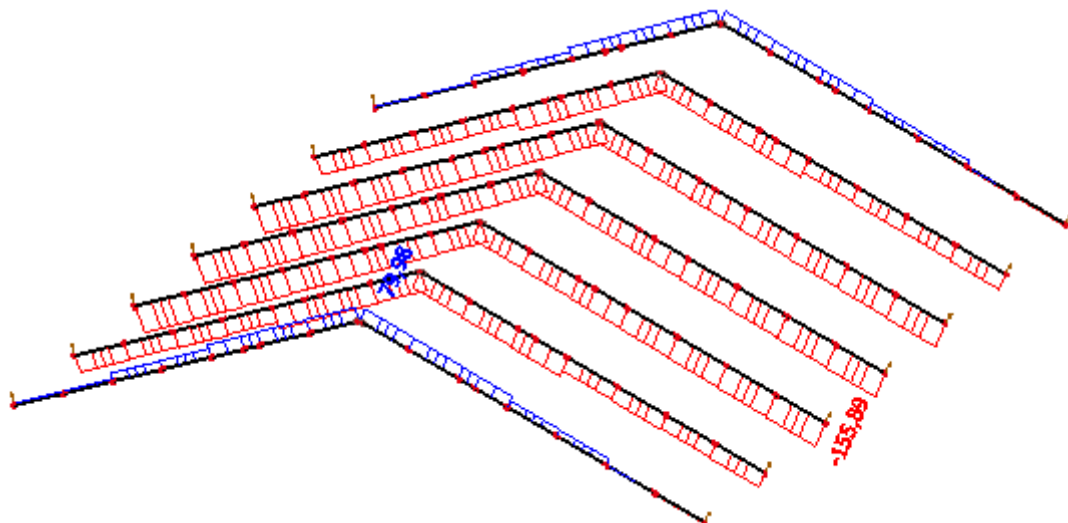
*Dijagram momenata savijanja (My)*

Poprečne sile u gredi (Vz)



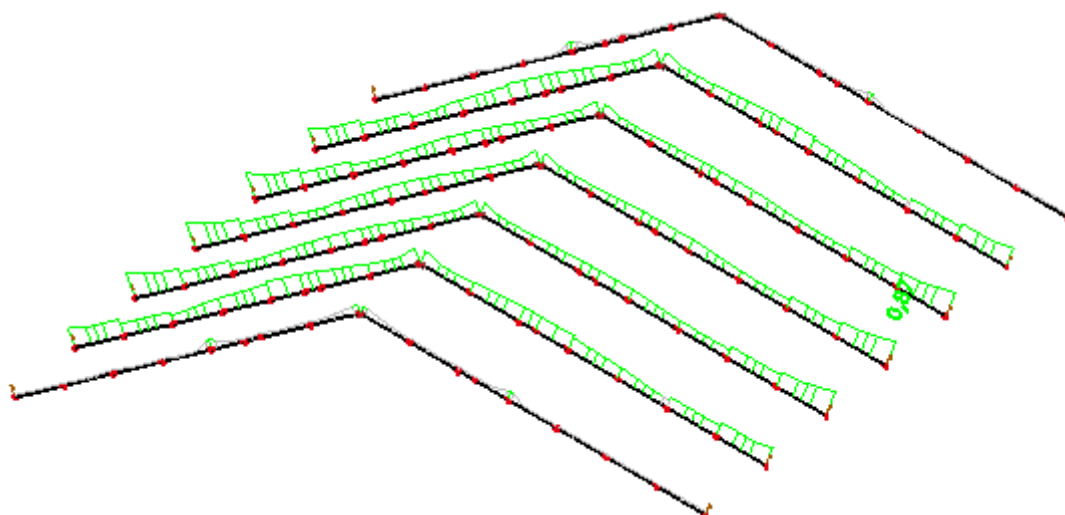
*Dijagram poprečnih sila (Vz)*

Uzdužna sila u gredi (N)



*Dijagram uzudžnih sila (N)*

Iskoristivost grede:



*Prikaz iskoristivosti grednog nosača*



**Timber ULS check**

Linear calculation, Extreme : Cross-section

Selection : All

Class : All ULS

Cross-section : greda - RECT (200; 760)

**EN 1995-1-1 Code Check**

Beam B21	14,020 m	greda - RECT (200; 760)	GL24h	All ULS	0,87 -
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**Combination key**

All ULS / 1.35\*težina + 1.35\*stalno + 1.35\*snijeg + 1.35\*vjetar p

**Basic data**Partial safety factor  $\gamma_M$  for Glued laminated timber 1,25**Material data**

Bending (fm,k)	24,0	MPa
Tension (ft,0,k)	16,5	MPa
Tension (ft,90,k)	0,4	MPa
Compression (fc,0,k)	24,0	MPa
Compression (fc,90,k)	2,7	MPa
Shear (fv,k)	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 14,020 m.

**Internal forces**

NEd	-155,89	kN
Vy,Ed	-0,15	kN
Vz,Ed	-73,32	kN
TEd	0,02	kNm
My,Ed	-257,71	kNm
Mz,Ed	-0,23	kNm

**Modification factor**

Service Class	1
Load duration	Short term
Modification factor $k_{mod}$	0,90

...: SECTION CHECK ...:

**Compression parallel to the grain**

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

$\sigma_{c,0,d}$	1,0	MPa
$f_{c,0,d}$	17,3	MPa
Unity check	0,06	-

**Compression perpendicular to the grain**

According to EN 1995-1-1 article 6.1.5 and formula (6.3)

$F_{c,90,d}$	73,32	kN
$I$	760	mm
$I_{ef}$	790	mm
$b$	200	mm
$A_{ef}$	158000	mm <sup>2</sup>
$\sigma_{c,90,d}$	0,5	MPa
Support condition	Discrete	
$h$	760	mm
$k_{c,90}$	1,00	-
$f_{c,90,d}$	1,9	MPa
Unity check	0,24	-

**Bending**

According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

$\sigma_{m,y,d}$	13,4	MPa
$k_{h,y}$	1,00	
$f_{m,y,d}$	17,3	MPa
$\sigma_{m,z,d}$	0,0	MPa
$k_{h,z}$	1,00	
$f_{m,z,d}$	17,3	MPa
$k_m$	0,70	

Unity check (6.11) = 0,77 + 0,00 = 0,78 -

Unity check (6.12) = 0,54 + 0,00 = 0,54 -

**Shear**

According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
$\tau_{y,d}$	0,0	MPa
$\tau_{z,d}$	1,1	MPa
$f_{v,d}$	1,9	MPa
Unity check $\tau_y$	0,00	-
Unity check $\tau_z$	0,56	-
Unity check Interaction	0,31	-

Note: The interaction equation has been added as a NCCI.

**Torsion**

According to EN 1995-1-1 article 6.1.8 and formula (6.14)

$\tau_{tor,d}$	0,0	MPa
kshape	1,57	
$f_{v,d}$	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,31	-

Note: The interaction equation has been added as a NCCI.

**Combined Bending and Axial Compression**

According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

$f_{c,0,d}$	17,3	MPa
$f_{m,y,d}$	17,3	MPa
$f_{m,z,d}$	17,3	MPa
km	0,70	

Unity check (6.19) =  $0,00 + 0,77 + 0,00 = 0,78$  -Unity check (6.20) =  $0,00 + 0,54 + 0,00 = 0,55$  -

The member satisfies the section check.

...: **STABILITY CHECK** ...**Columns subjected to compression or combined compression and bending**

According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	9,346	2,003	m
Buckling factor k	1,74	0,94	
Buckling length $L_{cr}$	16,235	1,880	m
Slenderness $\lambda$	74,00	32,56	-
Relative slenderness $\lambda$	1,19	0,52	-
Limit slenderness	0,30	0,30	-
Imperfection $\beta_c$	0,10	0,10	-
Reduction factor $k_c$	0,61	0,97	-

Unity check (6.23) =  $0,10 + 0,77 + 0,00 = 0,87$  -Unity check (6.24) =  $0,06 + 0,54 + 0,00 = 0,61$  -**Beams subjected to bending or combined bending and compression**

According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

<b>LTB Parameters</b>		
Elastic critical moment $M_{y,crit}$	3785,37	kNm
Critical bending stress $\sigma_{m,crit}$	196,6	MPa
Relative slenderness $\lambda_{rel,m}$	0,35	-
Reduction factor $k_{crit}$	1,00	-

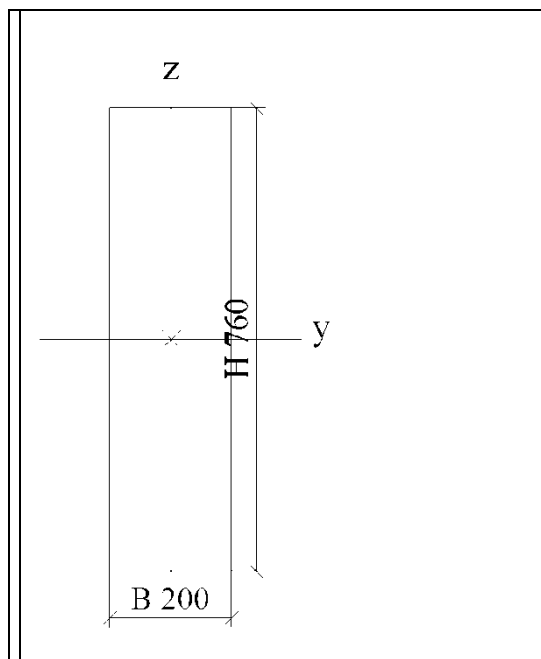
Unity check (6.33) =  $0,77$  -Unity check (6.35) =  $0,60 + 0,06 = 0,66$  -

<b><math>M_{y,crit}</math> Parameters</b>		
$G_{0,05}$	587,5	MPa
LTB length L	2,003	m
$L_{ef}/L$	0,90	
Effective length $L_{ef}$	1,802	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek nosača:

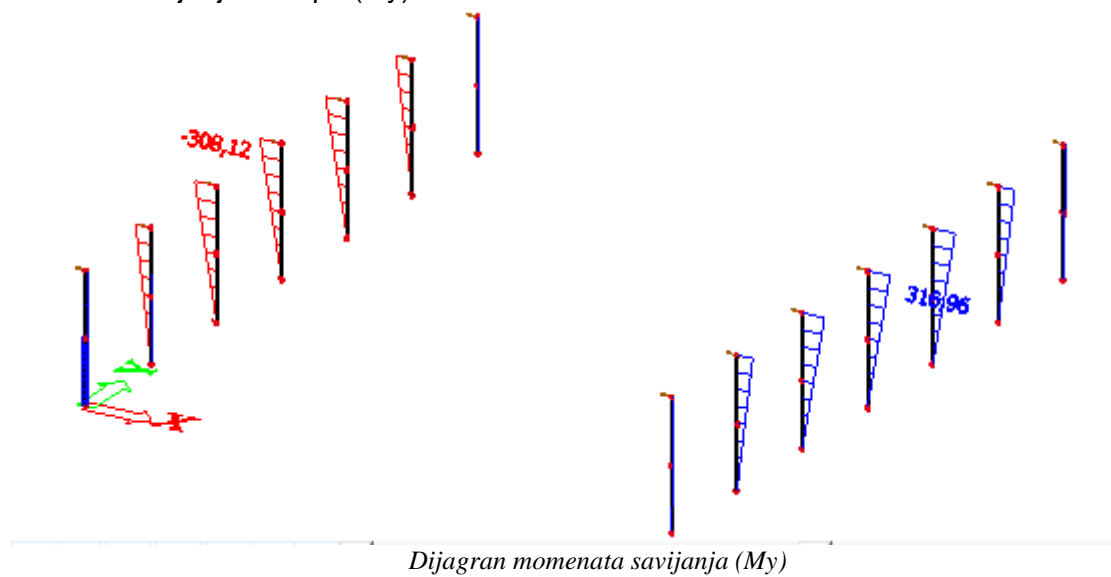
<b>Name</b>	greda
<b>Type</b>	RECT
<b>Detailed</b>	200; 760
<b>Item material</b>	GL24h
<b>Fabrication</b>	timber
<b>Use 2D FEM analysis</b>	✓



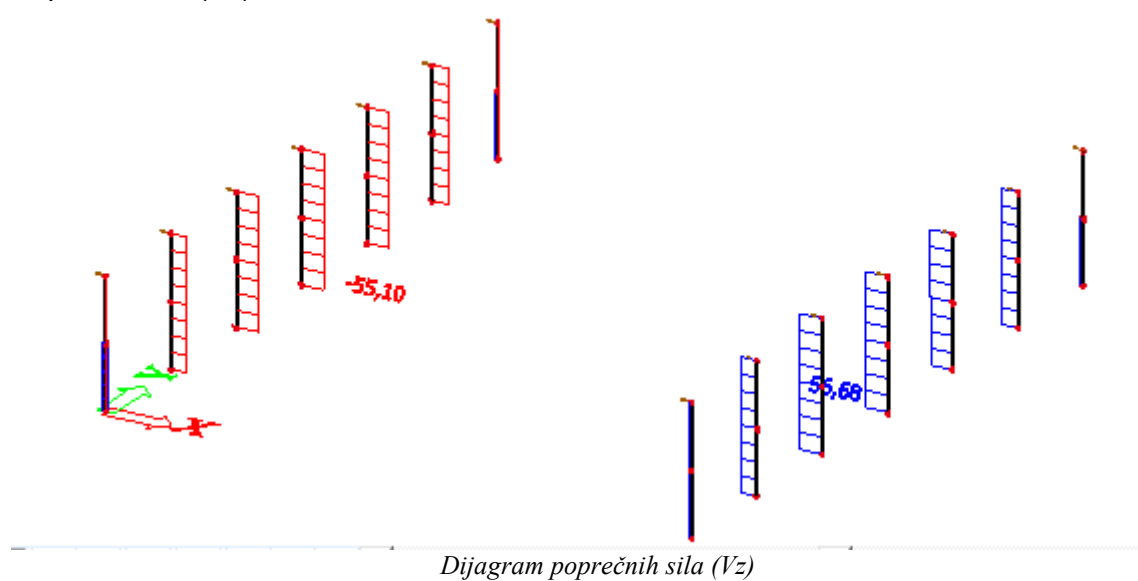
<b>A [m<sup>2</sup>]</b>	1,5200e-01	
<b>A y, z [m<sub>2</sub>]</b>	1,2667e-01	1,2667e-01
<b>I y, z [m<sub>4</sub>]</b>	7,3163e-03	5,0667e-04
<b>I w [m<sub>6</sub>], t [m<sub>4</sub>]</b>	1,7996e-05	1,6857e-03
<b>Wel y, z [m<sub>3</sub>]</b>	1,9253e-02	5,0667e-03
<b>Wpl y, z [m<sub>3</sub>]</b>	2,3532e-02	6,1926e-03
<b>d y, z [mm]</b>	0	0
<b>c YUCS, ZUCS [mm]</b>	100	380
<b>α [deg]</b>	0,00	
<b>A L, D [m<sub>2</sub>/m]</b>	1,9200e+00	1,9200e+00
<b>Mply +, - [Nm]</b>	5,65e+05	5,65e+05
<b>Mplz +, - [Nm]</b>	1,49e+05	1,49e+05

### 4.3 Dimenzioniranje stupa (poz. S)

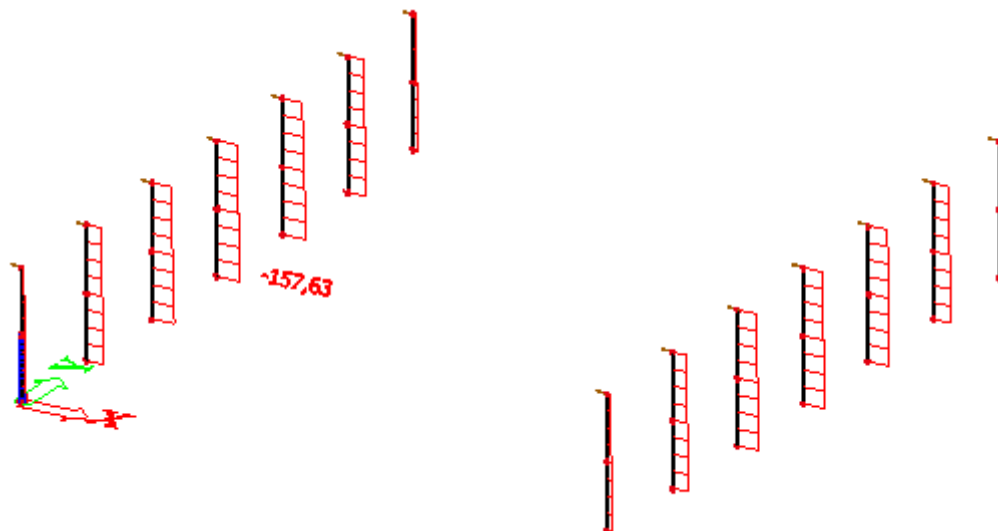
Moment savijanja u stupu (My)



Poprečna sila (Vz)

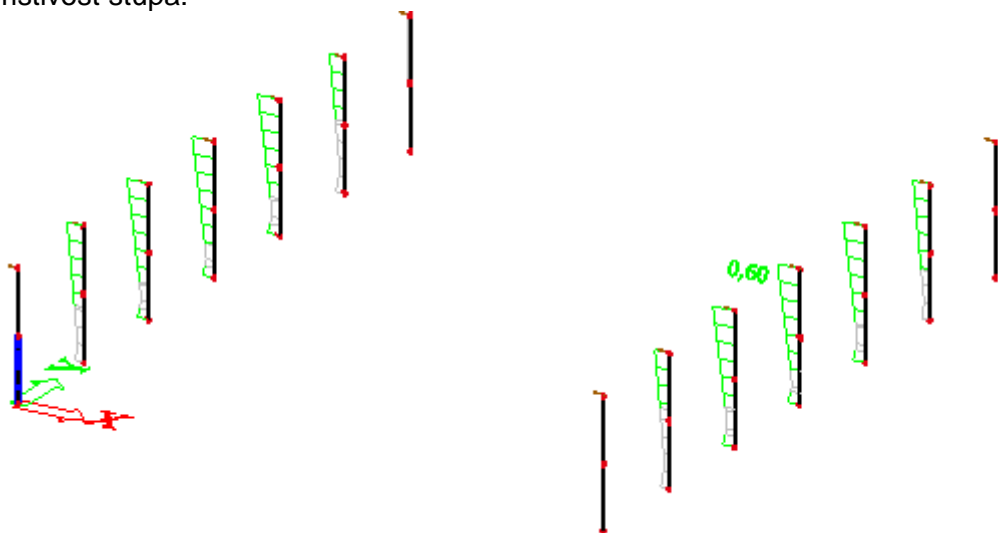


Uzdužna sila (N)



*Dijagram uzdužnih sila(N)*

Iskoristivost stupa:



*Prikaz iskoristivosti stupa*

**Timber ULS check**

Linear calculation, Extreme : Cross-section  
 Selection : All  
 Class : All ULS  
 Cross-section : stup - 2 Rect (200; 760; 200)

**EN 1995-1-1 Code Check**

Beam B18	5,600 m	2 - 2 Rect (200; 760; 200)	GL24h	All ULS	0,60 -
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**Combination key**

All ULS / 1.35\*težina + 1.35\*stalno + 1.35\*snijeg + 1.35\*vjetar p

**Basic data**

Partial safety factor $\gamma_M$ for Glued laminated timber	1,25
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**Material data**

Bending ( $f_{m,k}$ )	24,0	MPa
Tension ( $f_{t,0,k}$ )	16,5	MPa
Tension ( $f_{t,90,k}$ )	0,4	MPa
Compression ( $f_{c,0,k}$ )	24,0	MPa
Compression ( $f_{c,90,k}$ )	2,7	MPa
Shear ( $f_{v,k}$ )	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 5,600 m.

**Internal forces**

NEd	-135,51	kN
Vy,Ed	0,02	kN
Vz,Ed	56,52	kN
TEd	-0,07	kNm
My,Ed	316,96	kNm
Mz,Ed	0,01	kNm

**Modification factor**

Service Class	1
Load duration	Short term
Modification factor $k_{mod}$	0,90

...: SECTION CHECK ...:

**Compression parallel to the grain**

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

$\sigma_{c,0,d}$	0,4	MPa
$f_{c,0,d}$	17,3	MPa
Unity check	0,03	-

**Compression perpendicular to the grain**

According to EN 1995-1-1 article 6.1.5 and formula (6.3)

$F_{c,90,d}$	56,52	kN
$I$	760	mm
$I_{ef}$	790	mm
$b$	400	mm
$A_{ef}$	316000	mm <sup>2</sup>
$\sigma_{c,90,d}$	0,2	MPa
Support condition	Discrete	
$h$	760	mm
$k_{c,90}$	1,00	-
$f_{c,90,d}$	1,9	MPa
Unity check	0,09	-

**Bending**

According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

$\sigma_{m,y,d}$	8,2	MPa
$k_{h,y}$	1,00	
$f_{m,y,d}$	17,3	MPa
$\sigma_{m,z,d}$	0,0	MPa
$k_{h,z}$	1,00	
$f_{m,z,d}$	17,3	MPa
$k_m$	1,00	

Unity check (6.11) = 0,48 + 0,00 = 0,48 -

Unity check (6.12) = 0,48 + 0,00 = 0,48 -

**Shear**

According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
$\tau_{y,d}$	0,0	MPa
$\tau_{z,d}$	0,4	MPa
$f_{v,d}$	1,9	MPa
Unity check $\tau_y$	0,00	-
Unity check $\tau_z$	0,21	-
Unity check Interaction	0,05	-

Note: The interaction equation has been added as a NCCI.

**Torsion**

According to EN 1995-1-1 article 6.1.8 and formula (6.14)

$\tau_{tor,d}$	0,0	MPa
kshape	1,00	
$f_{v,d}$	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,05	-

Note: The interaction equation has been added as a NCCI.

**Combined Bending and Axial Compression**

According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

$f_{c,0,d}$	17,3	MPa
$f_{m,y,d}$	17,3	MPa
$f_{m,z,d}$	17,3	MPa
km	1,00	

Unity check (6.19) = 0,00 + 0,48 + 0,00 = 0,48 -

Unity check (6.20) = 0,00 + 0,48 + 0,00 = 0,48 -

The member satisfies the section check.

...: **STABILITY CHECK** ...**Columns subjected to compression or combined compression and bending**

According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	5,600	2,800	m
Buckling factor k	5,14	0,99	
Buckling length $L_{cr}$	28,778	2,770	m
Slenderness $\lambda$	131,17	13,31	-
Relative slenderness $\lambda$	2,11	0,21	-
Limit slenderness	0,30	0,30	-
Imperfection $\beta_c$	0,10	0,10	-
Reduction factor $k_c$	0,21	1,00	-

Unity check (6.23) = 0,12 + 0,48 + 0,00 = 0,60 -

Unity check (6.24) = 0,03 + 0,48 + 0,00 = 0,50 -

**Beams subjected to bending or combined bending and compression**

According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

<b>LTB Parameters</b>		
Elastic critical moment $M_{y,crit}$	17551,01	kNm
Critical bending stress $\sigma_{m,crit}$	455,8	MPa
Relative slenderness $\lambda_{rel,m}$	0,23	-
Reduction factor $k_{crit}$	1,00	-

Unity check (6.33) = 0,48 -

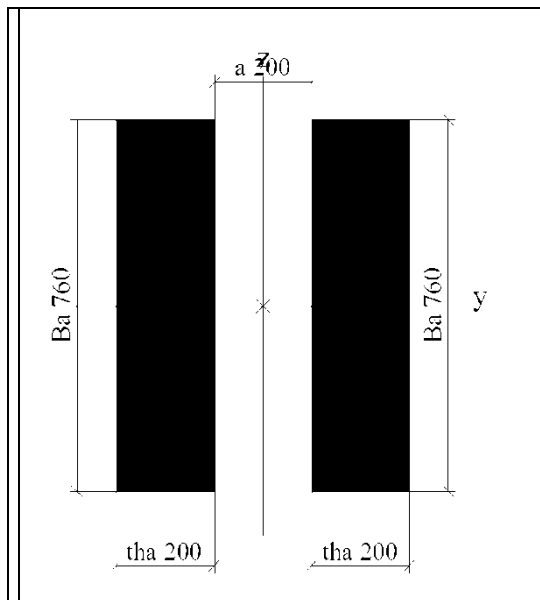
Unity check (6.35) = 0,23 + 0,03 = 0,25 -

<b><math>M_{y,crit}</math> Parameters</b>		
$G_{0,05}$	587,5	MPa
LTB length L	2,800	m
$L_{ef}/L$	1,00	
Effective length $L_{ef}$	2,800	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek stupa:

Name	stup
Type	2 Rect
Detailed	200; 760; 200
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓

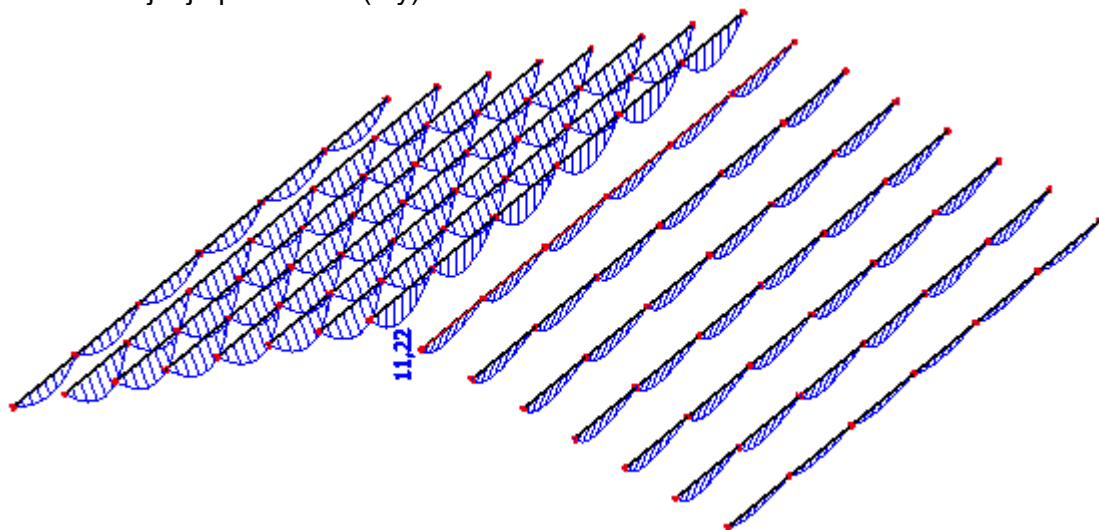


A [m <sub>2</sub> ]	3,0400e-01	
A <sub>y, z</sub> [m <sub>2</sub> ]	2,5333e-01	2,5333e-01
I <sub>y, z</sub> [m <sub>4</sub> ]	1,4633e-02	1,3173e-02
I <sub>w</sub> [m <sub>6</sub> ], t [m <sub>4</sub> ]	6,1957e-04	3,3635e-03
W <sub>el y, z</sub> [m <sub>3</sub> ]	3,8507e-02	4,3911e-02
W <sub>pl y, z</sub> [m <sub>3</sub> ]	4,7064e-02	4,5670e-02
d <sub>y, z</sub> [mm]	0	0
c <sub>YUCS, ZUCS</sub> [mm]	300	380
α [deg]	0,00	
A <sub>L, D</sub> [m <sub>2</sub> /m]	3,8400e+00	3,8400e+00
M <sub>ply +, -</sub> [Nm]	1,13e+06	1,13e+06
M <sub>plz +, -</sub> [Nm]	1,10e+06	1,10e+06



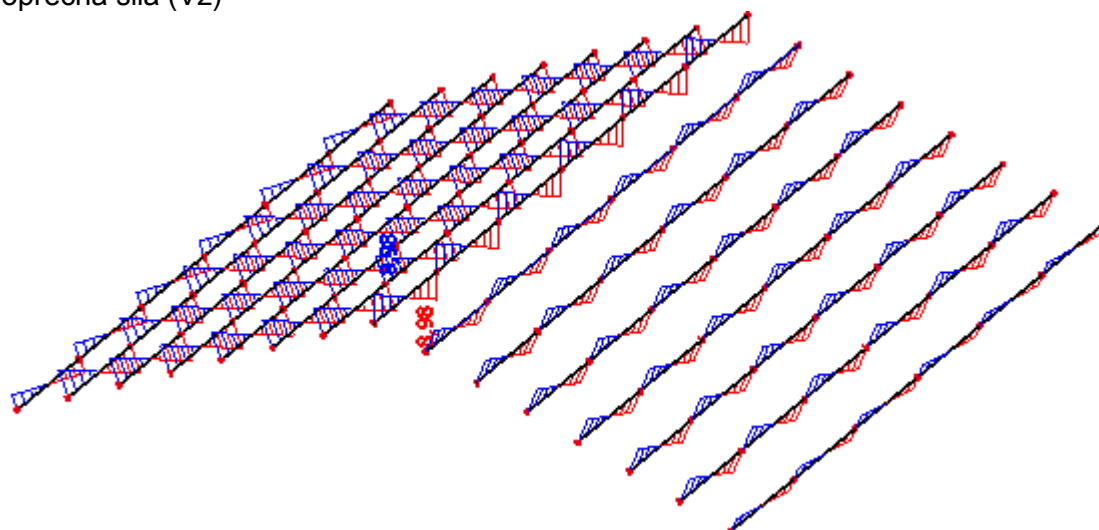
#### 4.4 Dimenzioniranje krovne podrožnice (poz. KP1 i KP2)

Moment savijanja podrožnice( $M_y$ )



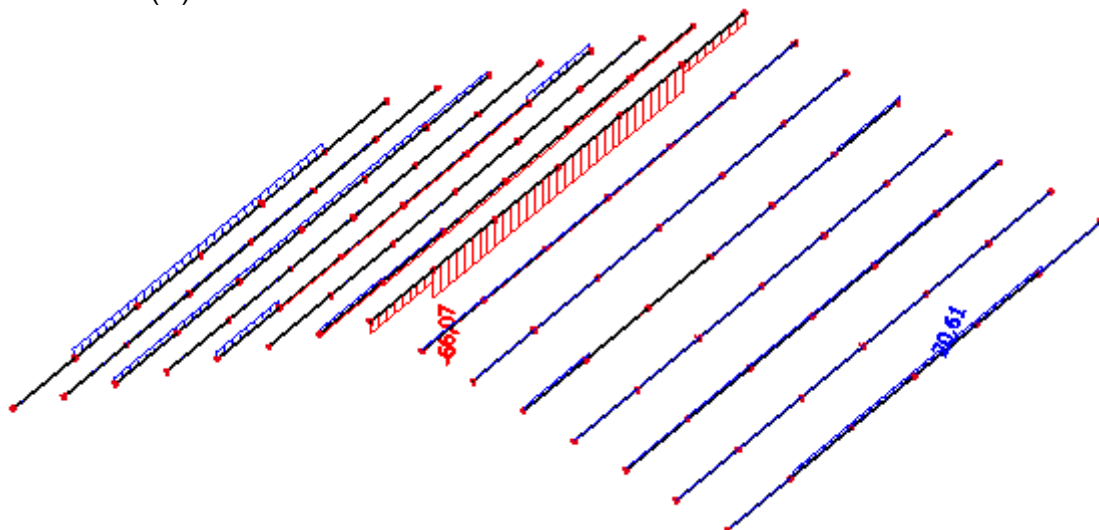
*Dijagram momenata savijanja ( $M_y$ )*

Poprečna sila ( $V_z$ )



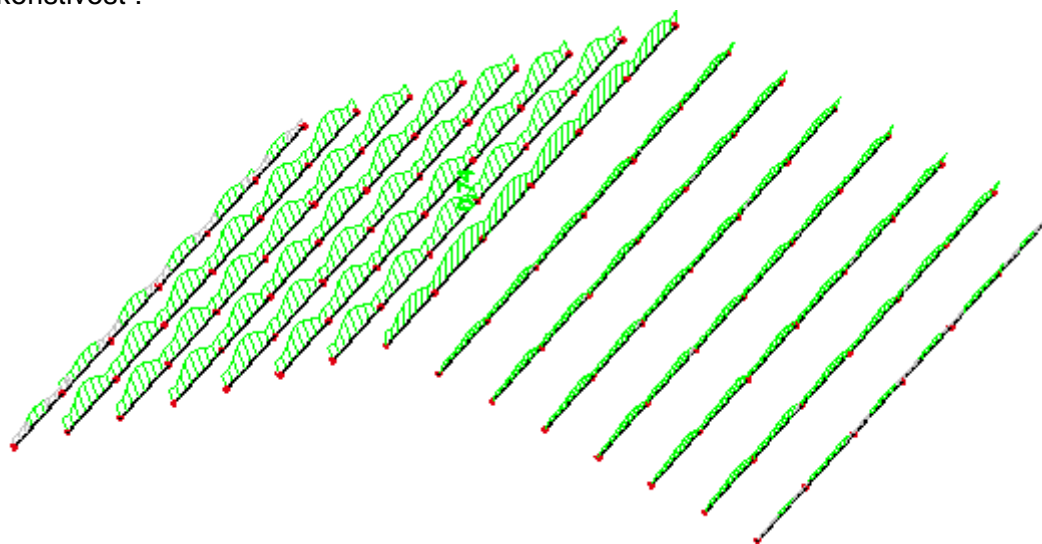
*Dijagram poprečnih sila ( $V_z$ )*

Uzdužna sila(N)



*Dijagram uzdužnih sila (N)*

Iskoristivost :



### Prikaz iskoristivosti presjeka

**Timber ULS check**

Linear calculation, Extreme : Cross-section  
 Selection : All  
 Class : All ULS  
 Cross-section : krovna podr - RECT (120; 240)

**EN 1995-1-1 Code Check**

Beam B46	5,000 m	krovna podr - RECT (120; 240)	GL24h	All ULS	0,74 -
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**Combination key**

All ULS / 1.35\*težina + 1.35\*stalno + 1.35\*snijeg + 1.35\*vjetar p

**Basic data**

Partial safety factor  $\gamma_M$  for Glued laminated timber 1,25

**Material data**

Bending ( $f_{m,k}$ )	24,0	MPa
Tension ( $f_{t,0,k}$ )	16,5	MPa
Tension ( $f_{t,90,k}$ )	0,4	MPa
Compression ( $f_{c,0,k}$ )	24,0	MPa
Compression ( $f_{c,90,k}$ )	2,7	MPa
Shear ( $f_{v,k}$ )	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 3,125 m.

**Internal forces**

NEd	-66,07	kN
Vy,Ed	0,92	kN
Vz,Ed	-2,24	kN
TEd	-0,73	kNm
My,Ed	10,52	kNm
Mz,Ed	0,62	kNm

**Modification factor**

Service Class	1
Load duration	Short term
Modification factor $k_{mod}$	0,90

...: SECTION CHECK ...:

**Compression parallel to the grain**

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

$\sigma_{c,0,d}$	2,3	MPa
$f_{c,0,d}$	17,3	MPa
Unity check	0,13	-

**Bending**

According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

$\sigma_{m,y,d}$	9,1	MPa
$k_{h,y}$	1,10	
$f_{m,y,d}$	18,9	MPa
$\sigma_{m,z,d}$	1,1	MPa
$k_{h,z}$	1,00	
$f_{m,z,d}$	17,3	MPa
$k_m$	0,70	

Unity check (6.11) = 0,48 + 0,04 = 0,53 -

Unity check (6.12) = 0,34 + 0,06 = 0,40 -

**Shear**

According to EN 1995-1-1 article 6.1.7 and formula (6.13)

$k_{cr}$	0,67	
$\tau_{y,d}$	0,1	MPa
$\tau_{z,d}$	0,2	MPa
$f_{v,d}$	1,9	MPa
Unity check $\tau_y$	0,04	-
Unity check $\tau_z$	0,09	-
Unity check Interaction	0,01	-

Note: The interaction equation has been added as a NCCI.

**Torsion**

According to EN 1995-1-1 article 6.1.8 and formula (6.14)

$\tau_{tor,d}$	0,9	MPa
kshape	1,30	
$f_{v,d}$	1,9	MPa
Unity check	0,34	-
Unity check Interaction Shear	0,35	-

Note: The interaction equation has been added as a NCCI.

**Combined Bending and Axial Compression**

According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

$f_{c,0,d}$	17,3	MPa
$f_{m,y,d}$	18,9	MPa
$f_{m,z,d}$	17,3	MPa
km	0,70	

Unity check (6.19) = 0,02 + 0,48 + 0,04 = 0,54 -

Unity check (6.20) = 0,02 + 0,34 + 0,06 = 0,42 -

The member satisfies the section check.

...: **STABILITY CHECK** ...**Columns subjected to compression or combined compression and bending**

According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	5,000	5,000	m
Buckling factor k	1,00	0,51	
Buckling length L <sub>cr</sub>	5,000	2,549	m
Slenderness $\lambda$	72,17	73,57	-
Relative slenderness $\lambda$	1,16	1,18	-
Limit slenderness	0,30	0,30	-
Imperfection $\beta_c$	0,10	0,10	-
Reduction factor k <sub>c</sub>	0,63	0,61	-

Unity check (6.23) = 0,21 + 0,48 + 0,04 = 0,74 -

Unity check (6.24) = 0,22 + 0,34 + 0,06 = 0,62 -

**Beams subjected to bending or combined bending and compression**

According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment $M_{y,crit}$	93,85	kNm
Critical bending stress $\sigma_{m,crit}$	81,5	MPa
Relative slenderness $\lambda_{rel,m}$	0,54	-
Reduction factor k <sub>crit</sub>	1,00	-

Unity check (6.33) = 0,48 -

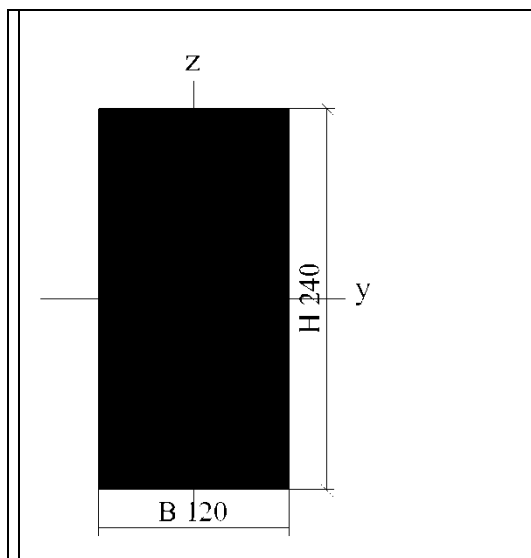
Unity check (6.35) = 0,23 + 0,22 = 0,45 -

My,crit Parameters		
G <sub>0,05</sub>	587,5	MPa
LTB length L	5,000	m
L <sub>ef</sub> /L	0,90	
Effective length L <sub>ef</sub>	4,500	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek:

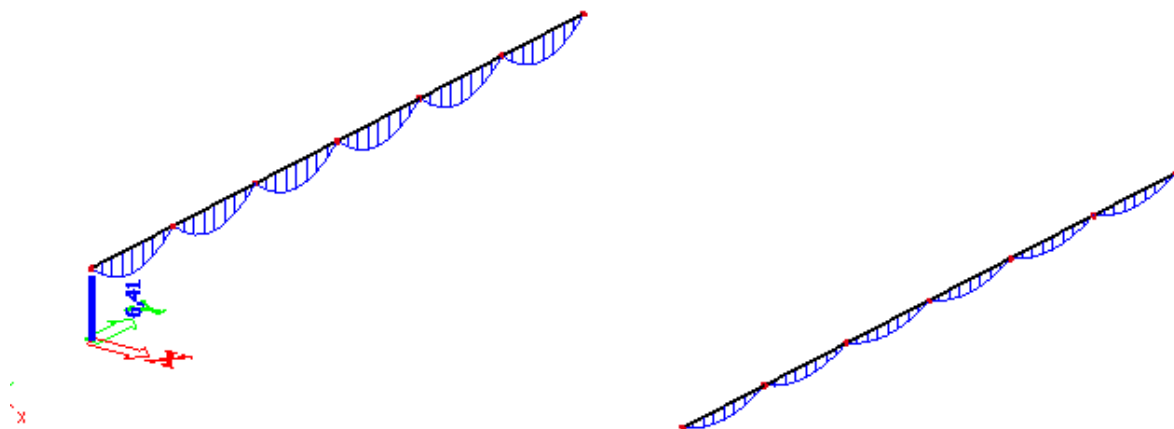
<b>Name</b>	krovna podr
<b>Type</b>	RECT
<b>Detailed</b>	120; 240
<b>Item material</b>	GL24h
<b>Fabrication</b>	timber
<b>Use 2D FEM analysis</b>	✓



<b>A [m<sub>2</sub>]</b>	2,8800e-02	
<b>A y, z [m<sub>2</sub>]</b>	2,4000e-02	2,4000e-02
<b>I y, z [m<sub>4</sub>]</b>	1,3824e-04	3,4560e-05
<b>I w [m<sub>6</sub>], t [m<sub>4</sub>]</b>	6,0039e-08	9,4694e-05
<b>Wel y, z [m<sub>3</sub>]</b>	1,1520e-03	5,7600e-04
<b>Wpl y, z [m<sub>3</sub>]</b>	1,4080e-03	7,0400e-04
<b>d y, z [mm]</b>	0	0
<b>c YUCS, ZUCS [mm]</b>	60	120
<b>α [deg]</b>	0,00	
<b>A L, D [m<sub>2</sub>/m]</b>	7,2000e-01	7,2000e-01
<b>Mply +, - [Nm]</b>	3,38e+04	3,38e+04
<b>Mplz +, - [Nm]</b>	1,69e+04	1,69e+04

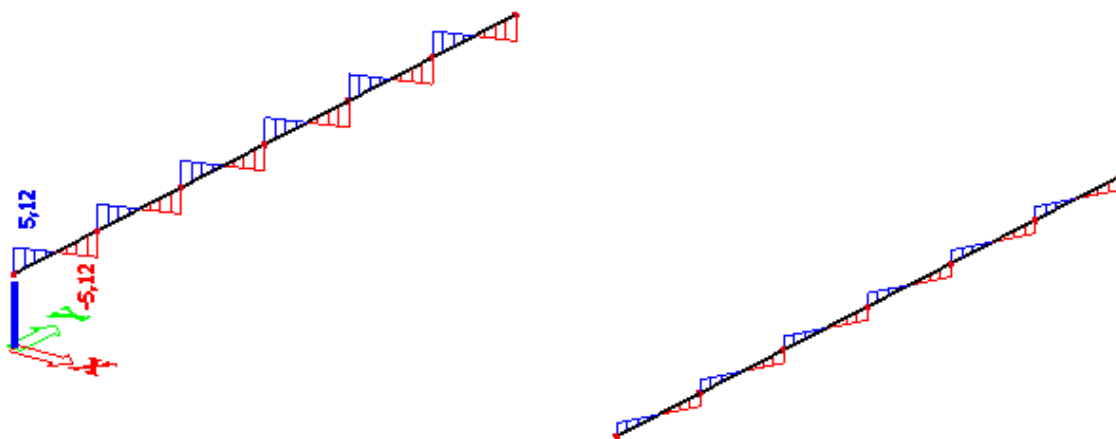
#### 4.5 Dimenzioniranje bočne podrožnice (poz. BP1 i BP2)

Moment savijanja ( $M_y$ )



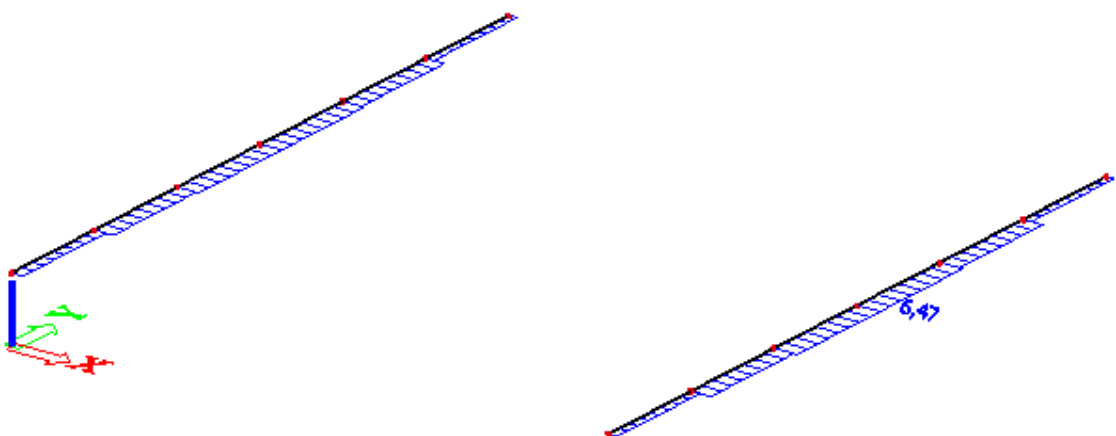
*Dijagram momenata savijanja ( $M_y$ )*

Poprečna sila ( $V_z$ )



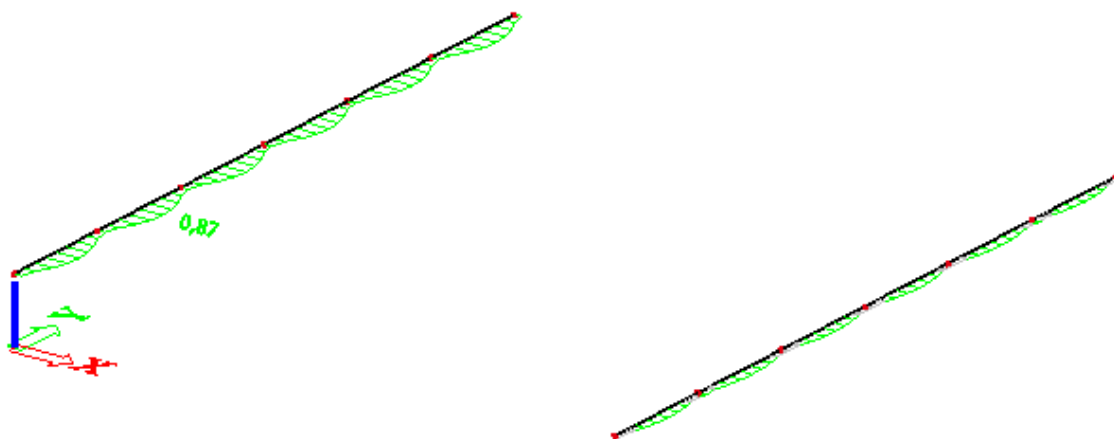
*Dijagram poprečnih sila ( $V_z$ )*

Uzdužna sila ( $N$ )



*Dijagram uzdužnih sila ( $N$ )*

Iskoristivost:



*Prikaz iskoristivosti*

**Timber ULS check**

Linear calculation, Extreme : Cross-section

Selection : All

Class : All ULS

Cross-section : bocna podr - RECT (120; 180)

**EN 1995-1-1 Code Check**

Beam B64	5,000 m	bocna podr - RECT (120; 180)	GL24h	All ULS	0,87 -
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**Combination key**

All ULS / 1.35\*tezina + 1.35\*stalno + 1.50\*vjetar p

**Basic data**Partial safety factor  $\gamma_M$  for Glued laminated timber 1,25**Material data**

Bending ( $f_{m,k}$ )	24,0	MPa
Tension ( $f_{t,0,k}$ )	16,5	MPa
Tension ( $f_{t,90,k}$ )	0,4	MPa
Compression ( $f_{c,0,k}$ )	24,0	MPa
Compression ( $f_{c,90,k}$ )	2,7	MPa
Shear ( $f_{v,k}$ )	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 2,500 m.

**Internal forces**

NEd	2,49	kN
Vy,Ed	0,00	kN
Vz,Ed	0,04	kN
TEd	0,00	kNm
My,Ed	0,03	kNm
Mz,Ed	6,41	kNm

**Modification factor**

Service Class	1
Load duration	Short term
Modification factor $k_{mod}$	0,90

...: SECTION CHECK ...:

**Tension parallel to the grain**

According to EN 1995-1-1 article 6.1.2 and formula (6.1)

$\sigma_{t,0,d}$	0,1	MPa
kh	1,10	
$f_{t,0,d}$	13,1	MPa
Unity check	0,01	-

**Bending**

According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

$\sigma_{m,y,d}$	0,0	MPa
kh,y	1,10	
$f_{m,y,d}$	19,0	MPa
$\sigma_{m,z,d}$	14,8	MPa
kh,z	1,00	
$f_{m,z,d}$	17,3	MPa
km	0,70	

Unity check (6.11) = 0,00 + 0,60 = 0,60 -

Unity check (6.12) = 0,00 + 0,86 = 0,86 -

**Shear**

According to EN 1995-1-1 article 6.1.7 and formula (6.13)

kcr	0,67	
$\tau_{y,d}$	0,0	MPa
$\tau_{z,d}$	0,0	MPa
$f_{v,d}$	1,9	MPa
Unity check $\tau_y$	0,00	-
Unity check $\tau_z$	0,00	-
Unity check Interaction	0,00	-

Note: The interaction equation has been added as a NCCI.



**Torsion**

According to EN 1995-1-1 article 6.1.8 and formula (6.14)

$\tau_{tor,d}$	0,0	MPa
kshape	1,23	
$f_{v,d}$	1,9	MPa
Unity check	0,00	-
Unity check Interaction Shear	0,00	-

Note: The interaction equation has been added as a NCCI.

**Combined Bending and Axial Tension**

According to EN 1995-1-1 article 6.2.3 and formula (6.17),(6.18)

$f_{t,0,d}$	13,1	MPa
$f_{m,y,d}$	19,0	MPa
$f_{m,z,d}$	17,3	MPa
km	0,70	

Unity check (6.17) =  $0,01 + 0,00 + 0,60 = 0,61$  -Unity check (6.18) =  $0,01 + 0,00 + 0,86 = 0,87$  -

The member satisfies the section check.

**...: STABILITY CHECK :...****Beams subjected to bending or combined bending and compression**

According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment $M_{y,crit}$	58,61	kNm
Critical bending stress $\sigma_{m,crit}$	90,5	MPa
Relative slenderness $\lambda_{rel,m}$	0,52	-
Reduction factor $k_{crit}$	1,00	-

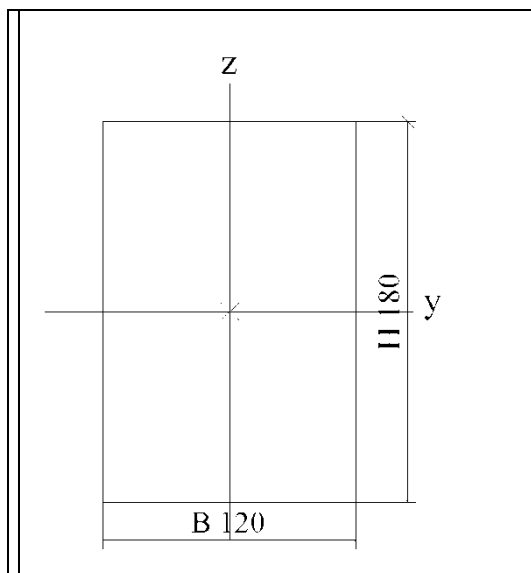
Unity check (6.33) = 0,00 -

My,crit Parameters		
G0,05	587,5	MPa
LTB length L	5,000	m
Lef/L	1,00	
Effective length Lef	5,000	m
Load position	normal	

The member satisfies the stability check.

Poprečni presjek:

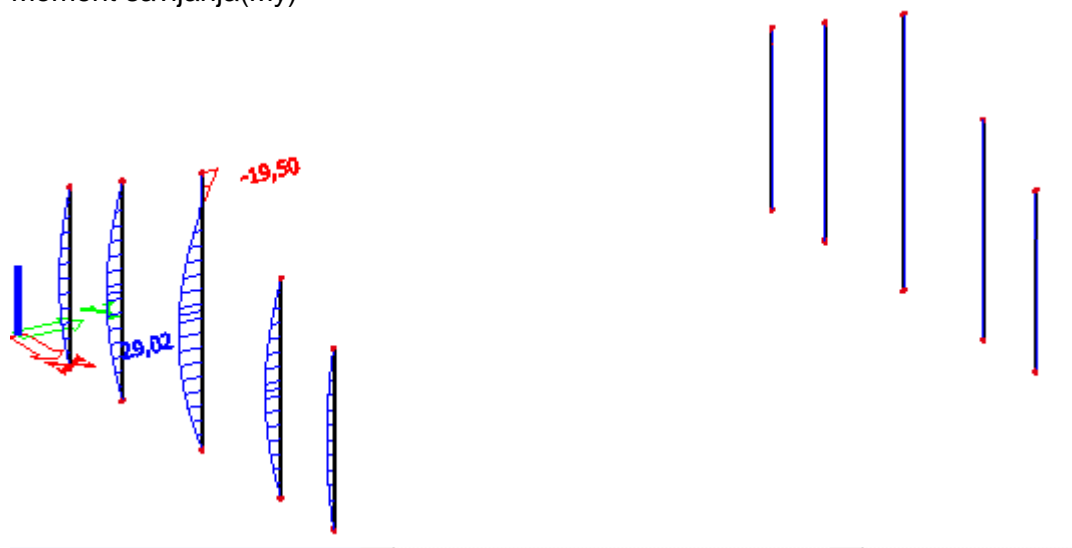
<b>Name</b>	bocna podr
<b>Type</b>	RECT
<b>Detailed</b>	120; 180
<b>Item material</b>	GL24h
<b>Fabrication</b>	timber
<b>Use 2D FEM analysis</b>	✓



<b>A [m<sub>2</sub>]</b>	2,1600e-02	
<b>A<sub>y, z</sub> [m<sub>2</sub>]</b>	1,8000e-02	1,8000e-02
<b>I<sub>y, z</sub> [m<sub>4</sub>]</b>	5,8320e-05	2,5920e-05
<b>I<sub>w</sub> [m<sub>6</sub>], t [m<sub>4</sub>]</b>	1,1144e-08	6,0795e-05
<b>W<sub>el y, z</sub> [m<sub>3</sub>]</b>	6,4800e-04	4,3200e-04
<b>W<sub>pl y, z</sub> [m<sub>3</sub>]</b>	7,9200e-04	5,2800e-04
<b>d<sub>y, z</sub> [mm]</b>	0	0
<b>c<sub>YUCS, ZUCS</sub> [mm]</b>	60	90
<b>α [deg]</b>	0,00	
<b>A<sub>L, D</sub> [m<sub>2</sub>/m]</b>	6,0000e-01	6,0000e-01
<b>M<sub>ply +, -</sub> [Nm]</b>	1,90e+04	1,90e+04
<b>M<sub>plz +, -</sub> [Nm]</b>	1,27e+04	1,27e+04

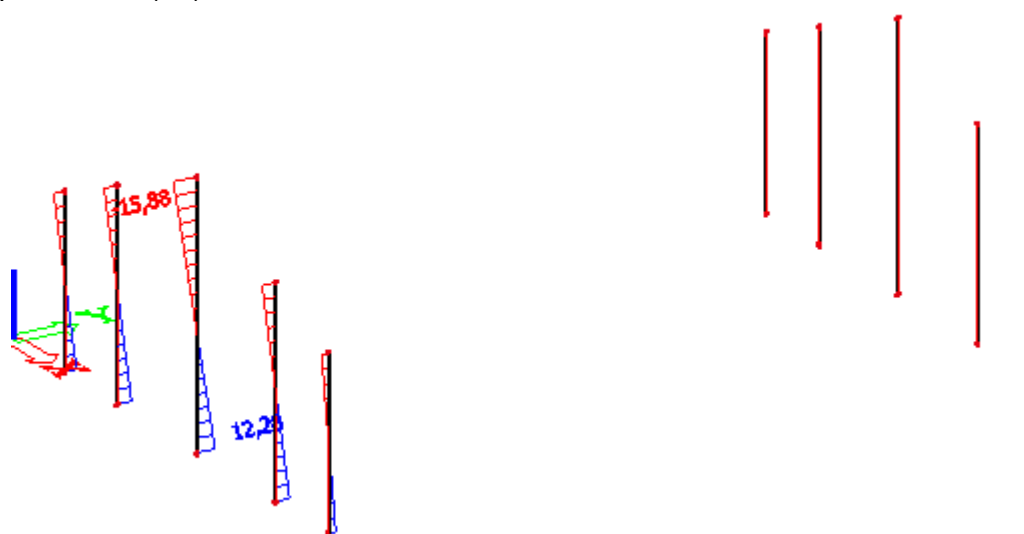
#### 4.6 Dimenzioniranje zabata (poz. ZS1, ZS2 i ZS3)

Moment savijanja ( $M_y$ )



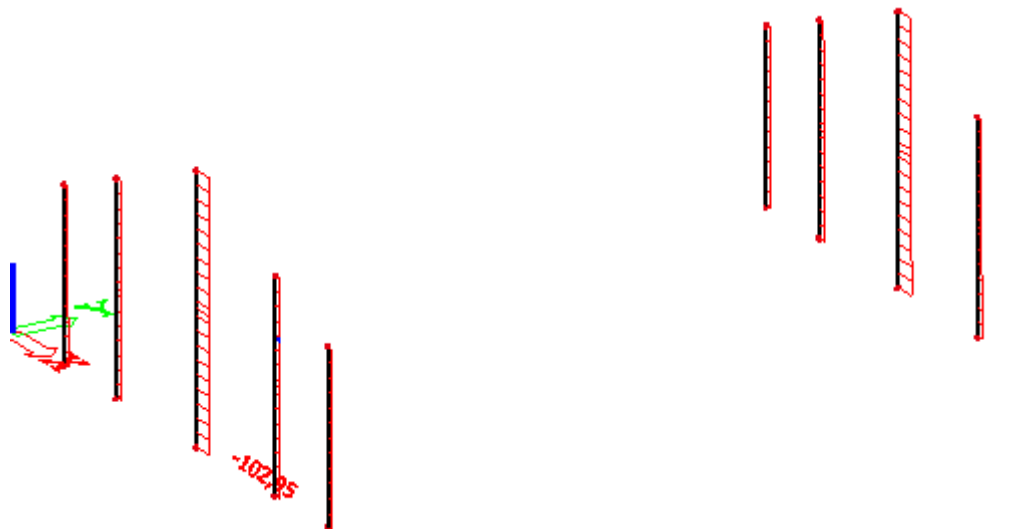
*Dijagram momenta savijanja ( $M_y$ )*

Poprečna sila ( $V_z$ )



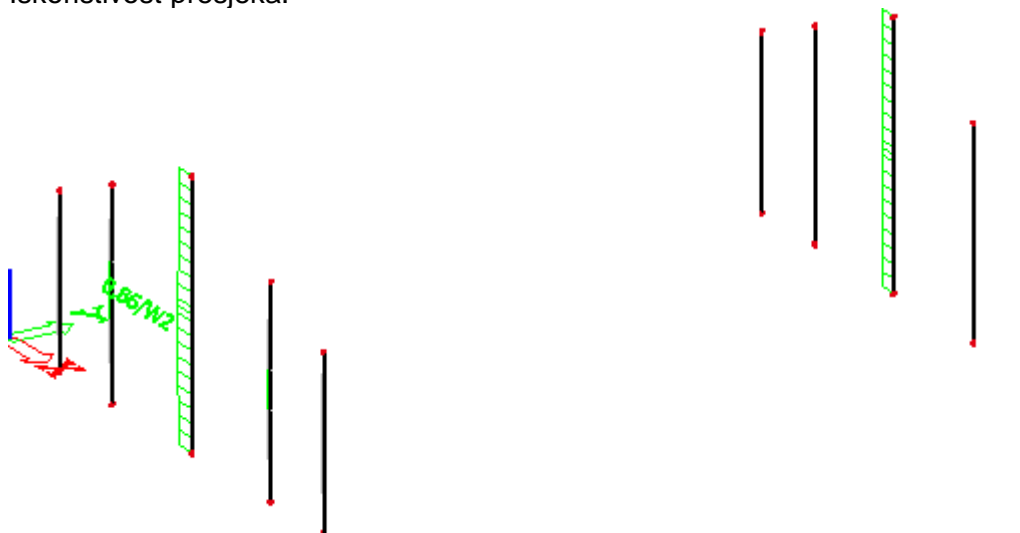
*Dijagram poprečnih sila ( $V_z$ )*

Uzdužna sila(N)



*Dijagram uzudžnih sila (N)*

Iskoristivost presjeka:



*Prikaz iskoristivosti presjeka*

**Timber ULS check**

Linear calculation, Extreme : Cross-section

Selection : All

Class : All ULS

Cross-section : zabat - RECT (220; 600)

**EN 1995-1-1 Code Check**

Beam B156	10,850 m	zabat - RECT (220; 600)	GL24h	All ULS	0,86 -
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**Combination key**

All ULS / 1.35\*tezina + 1.35\*stalno + 1.35\*snijeg + 1.35\*vjetar p

**Basic data**Partial safety factor  $\gamma_M$  for Glued laminated timber 1,25**Material data**

Bending ( $f_m, k$ )	24,0	MPa
Tension ( $f_t, 0, k$ )	16,5	MPa
Tension ( $f_t, 90, k$ )	0,4	MPa
Compression ( $f_c, 0, k$ )	24,0	MPa
Compression ( $f_c, 90, k$ )	2,7	MPa
Shear ( $f_v, k$ )	2,7	MPa
Type of timber	Glued laminated	

The critical check is on position 4,568 m.

**Internal forces**

NEd	-99,92	kN
Vy,Ed	0,30	kN
Vz,Ed	0,05	kN
TEd	0,00	kNm
My,Ed	0,21	kNm
Mz,Ed	13,04	kNm

**Modification factor**

Service Class	1
Load duration	Short term
Modification factor $k_{mod}$	0,90

...: SECTION CHECK ...:

**Compression parallel to the grain**

According to EN 1995-1-1 article 6.1.4 and formula (6.2)

$\sigma_{c,0,d}$	0,8	MPa
$f_{c,0,d}$	17,3	MPa
Unity check	0,04	-

**Bending**

According to EN 1995-1-1 article 6.1.6 and formula (6.11),(6.12)

$\sigma_{m,y,d}$	0,0	MPa
$k_{h,y}$	1,00	
$f_{m,y,d}$	17,3	MPa
$\sigma_{m,z,d}$	2,7	MPa
$k_{h,z}$	1,00	
$f_{m,z,d}$	17,3	MPa
$k_m$	0,70	

Unity check (6.11) = 0,00 + 0,11 = 0,11 -

Unity check (6.12) = 0,00 + 0,16 = 0,16 -

**Shear**

According to EN 1995-1-1 article 6.1.7 and formula (6.13)

$k_{cr}$	0,67	
$\tau_{y,d}$	0,0	MPa
$\tau_{z,d}$	0,0	MPa
$f_{v,d}$	1,9	MPa
Unity check $\tau_y$	0,00	-
Unity check $\tau_z$	0,00	-
Unity check Interaction	0,00	-

Note: The interaction equation has been added as a NCCI.

**Combined Bending and Axial Compression**

According to EN 1995-1-1 article 6.2.4 and formula (6.19),(6.20)

$f_{c,0,d}$	17,3	MPa
$f_{m,y,d}$	17,3	MPa
$f_{m,z,d}$	17,3	MPa
km	0,70	

Unity check (6.19) =  $0,00 + 0,00 + 0,11 = 0,11$  -Unity check (6.20) =  $0,00 + 0,00 + 0,16 = 0,16$  -

The member satisfies the section check.

**...: STABILITY CHECK ...****Columns subjected to compression or combined compression and bending**

According to EN 1995-1-1 article 6.3.2 and formula (6.23),(6.24)

Buckling parameters	yy	zz	
Sway type	sway	non-sway	
System length L	10,850	10,850	m
Buckling factor k	4,05	0,83	
Buckling length $L_{cr}$	43,919	9,037	m
Slenderness $\lambda$	253,57	142,30	-
Relative slenderness $\lambda$	4,08	2,29	-
Limit slenderness	0,30	0,30	-
Imperfection $\beta_c$	0,10	0,10	-
Reduction factor $k_c$	0,06	0,18	-

Unity check (6.23) =  $0,75 + 0,00 + 0,11 = 0,86$  -Unity check (6.24) =  $0,24 + 0,00 + 0,16 = 0,40$  -

Warning: The slenderness 253,57 is larger than the limit value 200,00!

**Beams subjected to bending or combined bending and compression**

According to EN 1995-1-1 article 6.3.3 and formula (6.33),(6.35)

LTB Parameters		
Elastic critical moment $M_{y,crit}$	634,57	kNm
Critical bending stress $\sigma_{m,crit}$	48,1	MPa
Relative slenderness $\lambda_{rel,m}$	0,71	-
Reduction factor $k_{crit}$	1,00	-

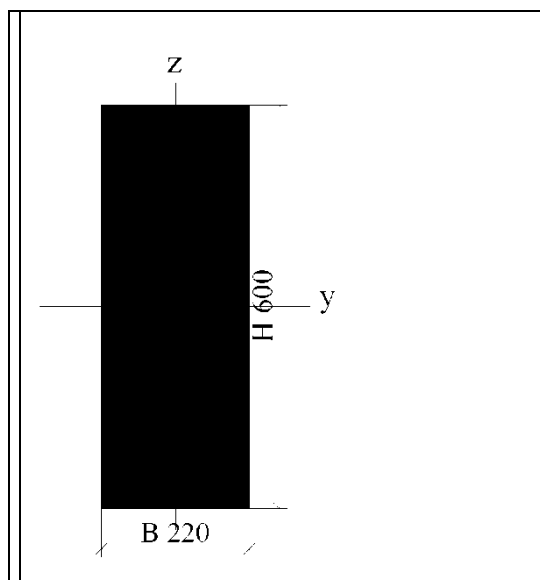
Unity check (6.33) =  $0,00$  -Unity check (6.35) =  $0,00 + 0,24 = 0,24$  -

My,crit Parameters		
$G_{0,05}$	587,5	MPa
LTB length L	10,850	m
$L_{ef}/L$	1,00	
Effective length $L_{ef}$	10,850	m
Load position	normal	

The member satisfies the stability check.

## Poprečni presjek

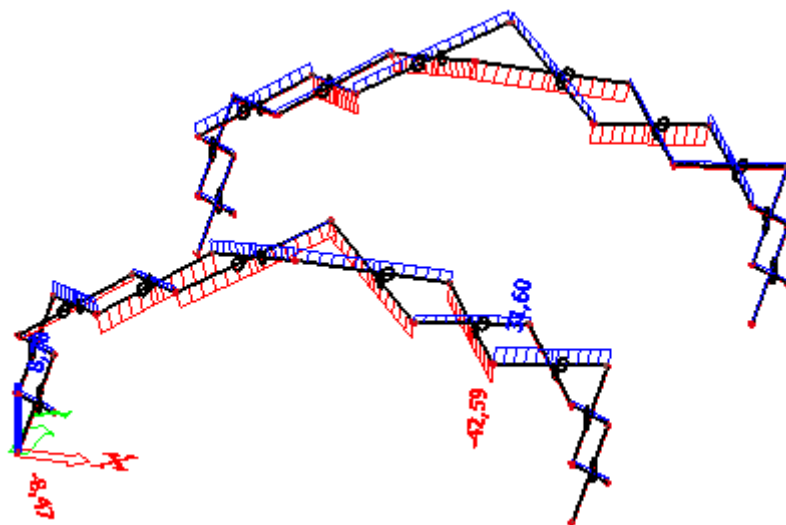
Name	zabat
Type	RECT
Detailed	220; 600
Item material	GL24h
Fabrication	timber
Use 2D FEM analysis	✓



A [m <sub>2</sub> ]	1,3200e-01	
A y, z [m <sub>2</sub> ]	1,1000e-01	1,1000e-01
I y, z [m <sub>4</sub> ]	3,9600e-03	5,3240e-04
I w [m <sub>6</sub> ], t [m <sub>4</sub> ]	9,1206e-06	1,6336e-03
Wel y, z [m <sub>3</sub> ]	1,3200e-02	4,8400e-03
Wpl y, z [m <sub>3</sub> ]	1,6133e-02	5,9156e-03
d y, z [mm]	0	0
c YUCS, ZUCS [mm]	110	300
α [deg]	0,00	
A L, D [m <sub>2</sub> /m]	1,6400e+00	1,6400e+00
Mply +, - [Nm]	3,87e+05	3,87e+05
Mplz +, - [Nm]	1,42e+05	1,42e+05

#### 4.7 Dimenzioniranje spregova – S235 (poz. KS1, KS2, BS1 i BS2)

Uzdužna sila:



*Dijagram uzudžnih sila (N)*

odabrano  $\varnothing 15$

$$A = 1,767 \cdot 10^{-4} \text{ m}^2$$

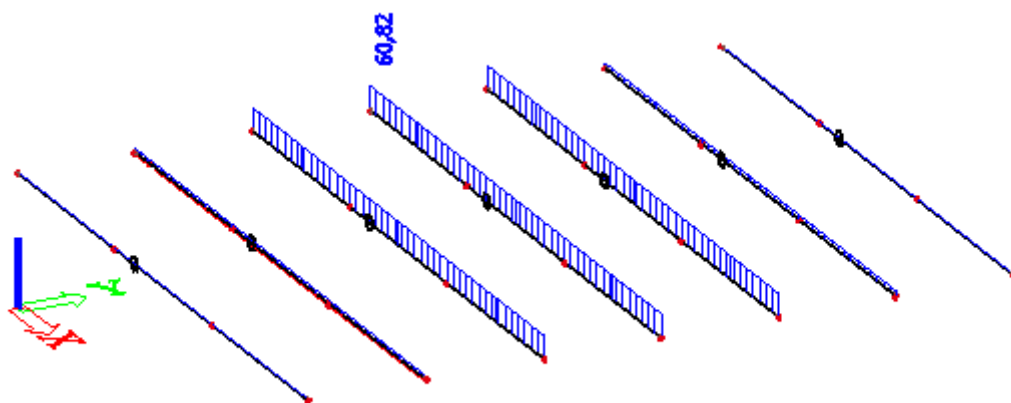
$$\frac{A \cdot f_y}{\gamma_{M_0}} = \frac{1,767 \cdot 23,5}{1,0} = 41,52 \text{ kN}$$

$41,52 \text{ kN} > 31,60 \text{ kN}$  - presjek zadovoljava



#### 4.8 Dimenzioniranje zatege – S235 (poz. Z)

Uzdužna sila:



*Dijagram uzudžnih sila (N)*

odabrano  $\varnothing 20$

$$A = 3,142 \cdot 10^{-4} \text{ m}^2$$

$$\frac{A \cdot f_y}{\gamma_{M_0}} = \frac{3,142 \cdot 23,5}{1,0} = 73,84 \text{ kN}$$

$73,84 \text{ kN} > 60,82 \text{ kN}$  - presjek zadovoljava

## 5. SPOJEVI

### 5.1 SPOJ STUPA I GREDE (trnovi)

Rezne sile:  $M_{Ed} = 316,96 \text{ kNm}$ ,  $V_{Ed} = 56,68 \text{ kN}$ ,  $N_{Ed} = 157,63 \text{ kN}$  (tlak)

Kvaliteta materijala:

Čelik: S355  $\rightarrow f_{uk} = 490 \text{ MPa}$

Drvo: LLD GL24h  $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2.  $\rightarrow$  kratkotrajno opterećenje  $\rightarrow k_{mod} = 0,90$

$\alpha=90^\circ$  -kut unosa opterećenja

$d_{odabrano} = 20 \text{ mm}$  –promjer trna

Minimalni razmaci trnova:

$$a_1 = (3 + 2|\cos\alpha|)d = (3 + 2|\cos 90|)20 = 60 \text{ mm}$$

$$a_2 = 3d = 3 \cdot 20 = 60 \text{ mm}$$

$$a_3 = \max(7d; 80 \text{ mm}) = \max(7 \cdot 20; 80 \text{ mm}) = 140 \text{ mm}$$

$$a_4 = \max((2 + 2\sin\alpha)d; 3d) = \max((2 + 2\sin 90) \cdot 20; 3 \cdot 20) = 80 \text{ mm}$$

$r_v = 270 \text{ mm}$  – radijus vanjske kružnice

$r_u = 210 \text{ mm}$  – radijus unutarnje kružnice

Potreban broj trnova:

$$n_v = \frac{2r\pi}{a_1; a_2} = \frac{2 \cdot 270\pi}{60} \rightarrow 28 \text{ komada}$$

$$n_v = \frac{2r\pi}{a_1; a_2} = \frac{2 \cdot 210\pi}{60} \rightarrow 21 \text{ komada}$$

Posmična otpornost jednog trna je najmanja od slijedećih vrijednosti:

$$R_d = \min \left\{ \begin{array}{l} \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{0.5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d)} \\ 1.05 \cdot \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[ \sqrt{2\beta(1 + \beta) + \frac{4\beta(2 + \beta) \cdot M_{y,Rd}}{f_{h,\alpha,d} \cdot t_1^2 \cdot d}} - \beta \right] \\ 1.15 \cdot \sqrt{\frac{2\beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} \end{array} \right\}$$

$\beta=1.0$  –za spojene elemente iste kvalitete drva

$t_1$  –širina grede

$t_2$  –širina stupa

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0,3 \cdot f_{uk} \cdot d^{2,6} = 0,3 \cdot 490 \cdot 20^{2,6} = 354\,810 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1,1} = 322\,554 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$$f_{h,0,k} = 0,082 \cdot (1 - 0,01 \cdot d) \cdot \rho_k = 0,082 \cdot (1 - 0,01 \cdot 20) \cdot 380 = 24,93 \text{ N/mm}^2$$

$$k_{90} = 0,9 + 0,015 \cdot d = 0,9 + 0,015 \cdot 20 = 1,2$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$\alpha = 45^\circ$  - najopterećeniji trn

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 45 + \cos^2 45} = 22,66 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{\text{mod}} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0,90 \cdot \frac{22,66}{1,25} = 16,32 \text{ N/mm}^2$$

Proračunska otpornost jednog trna:

$$f_{h,\alpha,d} \cdot t_1 \cdot d = 16,32 \cdot 200 \cdot 20 = 65\,280 \text{ N}$$

$$0,5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0,5 \cdot (16,32 \cdot 400 \cdot 20) = 65\,280 \text{ N}$$

$$1,05 \cdot \frac{f_{h,\alpha,d} \cdot t_1 \cdot d}{2 + \beta} \cdot \left[ \sqrt{2\beta(1 + \beta) + \frac{4\beta(2 + \beta) \cdot M_{y,Rd}}{f_{h,\alpha,d} \cdot t_1^2 \cdot d}} - \beta \right] =$$

$$= 1,05 \cdot \frac{16,32 \cdot 200 \cdot 20}{2 + 1} \cdot \left[ \sqrt{2(1 + 1) + \frac{4(2 + 1) \cdot 322\,554}{16,32 \cdot 200^2 \cdot 20}} - 1 \right] = 24\,918 \text{ N}$$

$$1,15 \cdot \sqrt{\frac{2\beta}{1 + \beta}} \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} = 1,15 \cdot \sqrt{\frac{2}{1 + 1}} \cdot \sqrt{2 \cdot 322\,554 \cdot 16,32 \cdot 20} =$$

$$= 17\,687 \text{ N}$$

$$\min R_d = 17\,687 \text{ N}$$

$$\Sigma R_d = 2 \cdot \min R_d = 2 \cdot 17\,687 = 35\,374 \text{ N} = 35,37 \text{ kN}$$

Doprinos jednog trna u prihvatanju unutrašnjih sila montažne veze:

Budući da su trnovi raspoređeni u 2 kružnice, trnovi prihvataju silu od momenta savijanja u omjeru radijusa kružnica:

$$\frac{r_u}{r_v} = \frac{210}{270} = \frac{7}{9} \rightarrow M_{d,v} = \frac{9}{16} M_{Ed} ; M_{d,u} = \frac{7}{16} M_{Ed}$$

-od momenta savijanja:

$$F_{M,d,v} = \frac{\frac{9}{16} M_{Ed}}{r \cdot n} = \frac{\frac{9}{16} \cdot 316,96}{0,27 \cdot 28} = 23,6 \text{ kN}$$

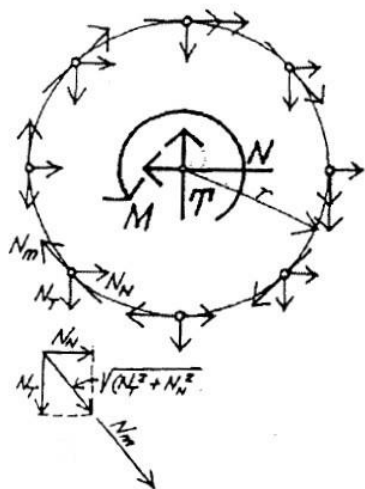
$$F_{M,d,u} = \frac{\frac{7}{16} M_{Ed}}{r \cdot n} = \frac{\frac{7}{16} \cdot 316,96}{0,21 \cdot 21} = 31,4 \text{ kN}$$

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{56,68}{49} = 1,16 \text{ kN}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{157,63}{49} = 3,21 \text{ kN}$$



Proračunska vrijednost sile koju preuzima 1 trn:

$$F_d = F_M + \sqrt{F_N^2 + F_V^2}$$

$$F_{d,v} = 23,6 + \sqrt{3,21^2 + 1,16^2} = 27,01 \text{ kN}$$

$$F_{d,u} = 31,4 + \sqrt{3,21^2 + 1,16^2} = 34,8 \text{ kN}$$

$$R_d = 35,37 \text{ kN} > F_d = 34,8 \text{ kN}$$

$$\eta = \frac{34,8}{35,37} = 0,98$$

## 5.2 MONTAŽNI SPOJ DVIJU GREDA-ZGLOB (trn, pločice i vijci)

Rezne sile:  $V_{Ed} = 44,70 \text{ kN}$ ,  $N_{Ed} = 116,31 \text{ kN}$

Kvaliteta materijala:

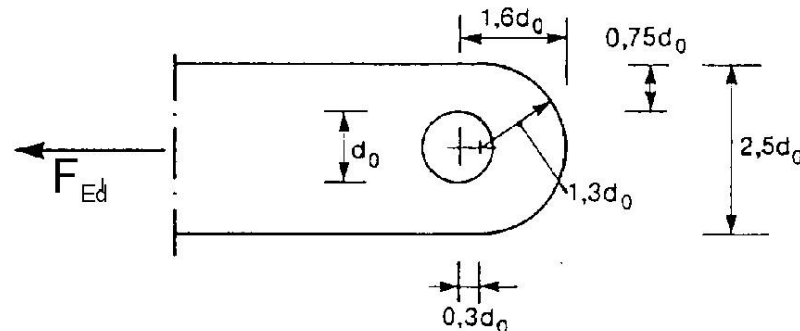
Čelik: S355  $\rightarrow f_{uk} = 490 \text{ MPa}$

Drvo: LLD GL24h  $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2.  $\rightarrow$  kratkotrajno opterećenje  $\rightarrow k_{mod} = 0,90$

### 5.2.1 Proračun trna i debljine pločica (P1) na zglobu

$d_{odabrano} = 26 \text{ mm}$  –promjer trna



Dimenzije pločice odabiru se prema preporukama sa slike.

Geometrijski uvjeti:

$$1. \quad t \geq 0,7 \cdot \sqrt{\frac{F_{Ed} \cdot \gamma_{M0}}{f_y}} = 0,7 \cdot \sqrt{\frac{116310 \cdot 1,0}{355}} = 12,67 \text{ mm}$$

$$2. \quad d_0 \leq 2,5 t$$

$$27 \text{ mm} \leq 2,5 \cdot 14 = 35 \text{ mm}$$

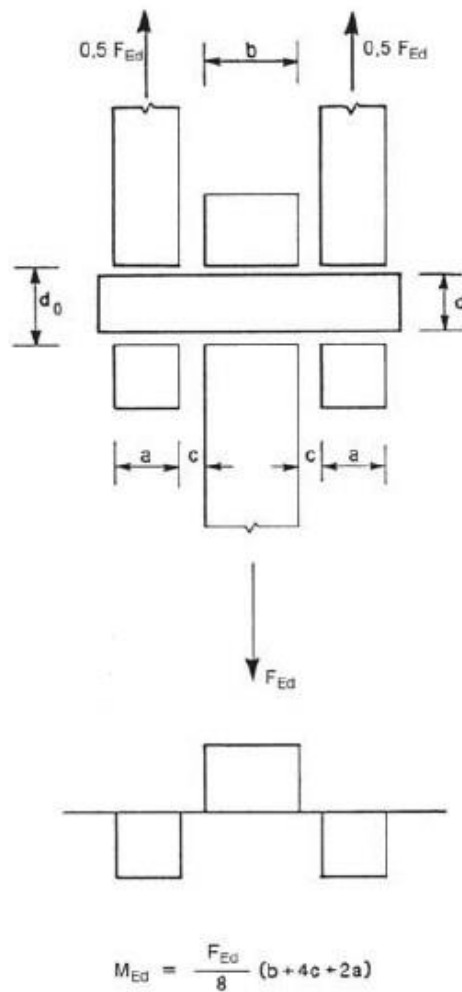
$\rightarrow$  Uvjeti zadovoljeni  $\rightarrow$  odabrana debljina pločice  $t = 14 \text{ mm}$

Otpornost trna savijanje:

$$M_{b,Rd} = \frac{1,5 \cdot W_{el} \cdot f_{yp}}{\gamma_{M0}} = \frac{1,5 \cdot 1689 \cdot 355}{1,0} = 899\,393 \text{ Nmm}$$

$$M_{Ed} = \frac{F_{Ed}}{8} \cdot (b + 4c + 2a) = \frac{116\,310}{8} \cdot (14 + 12 + 28) = 785\,093 \text{ Nmm}$$

Napomena: Moment savijanja izračunat je prema shemi sa slike.



$$M_{b,Rd} = 0,89 \text{ kNm} > M_{Ed} = 0,79 \text{ kNm}$$

→Uvjet zadovoljen

Posmična otpornost trna:

$$F_{V,Rd} = \frac{0,6 \cdot A \cdot f_{up}}{\gamma_{M2}} = \frac{0,6 \cdot 530,9 \cdot 490}{1,25} = 124\,867 \text{ N} = 124,87 \text{ kN}$$

$$F_{V,Ed} = 44,70 \text{ kN}$$

$$F_{V,Rd} > F_{V,Ed} \rightarrow \text{Uvjet zadovoljen}$$

Interakcija M+V:

$$\left(\frac{M_{Ed}}{M_{Rd}}\right)^2 + \left(\frac{F_{V,Ed}}{F_{V,Rd}}\right)^2 \leq 1$$

$$\left(\frac{0,79}{0,89}\right)^2 + \left(\frac{44,70}{124,87}\right)^2 \leq 1$$

$$0,92 \leq 1$$

Pritisak po omotaču rupe:

$$F_{b,Rd} = \frac{1,5 \cdot t \cdot d \cdot f_y}{\gamma_{M0}} = \frac{1,5 \cdot 14 \cdot 26 \cdot 355}{1,0} = 193\,830 \text{ N} = 193,83 \text{ kN}$$

$$F_{b,Ed} = 116,31 \text{ kN}$$

$$F_{b,Rd} > F_{b,Ed} \rightarrow \text{Uvjet zadovoljen}$$

Debljina pločice P2 i P3 je 26 mm.

Naprezanja na drvenoj gredi preko pločice P2:

$$f_{b,Ed} \leq k_{mod} \cdot \frac{f_{c,90,k}}{\gamma_M}$$

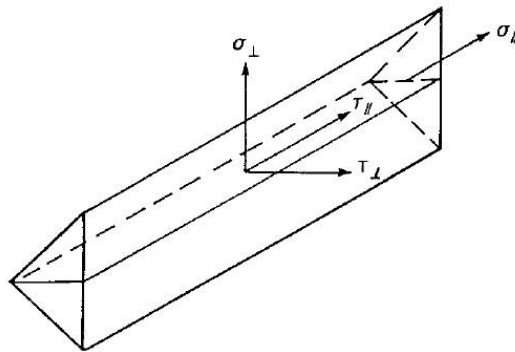
$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{116\,310}{460 \cdot 26} = 11,18 \text{ Mpa} < 0,90 \cdot \frac{26,5}{1,25} = 19,08 \text{ Mpa}$$

→ Uvjet zadovoljen

## 5.2.2 Proračun vara između pločica P1 i P2 direktnom metodom

a=7 mm –debljina vara

L=75 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{116\,310}{7 \cdot 75} = 221,54 \text{ MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80 \text{ MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{44\,700 \cdot 4\,921,88}{246\,093,80 \cdot 7} = 127,71 \text{ Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{7 \cdot 75^3}{12} = 246\,093,80 \text{ mm}^4 - \text{moment tromosti}$$

$$S = \frac{75}{2} \cdot 7 \cdot \frac{75}{4} = 4\,921,88 \text{ mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{116\,310 \cdot 459,38}{2\,143,80 \cdot 75} = 332,31 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{75 \cdot 7^3}{12} = 2\,143,80 \text{ mm}^4 - \text{moment tromosti}$$

$$S = 75 \cdot 3,5 \cdot 1,75 = 459,38 \text{ mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} = \frac{[221,54^2 + 3(332,31^2 + 127,71^2)]^{0.5}}{2} = 327,60 \text{ Mpa}$$

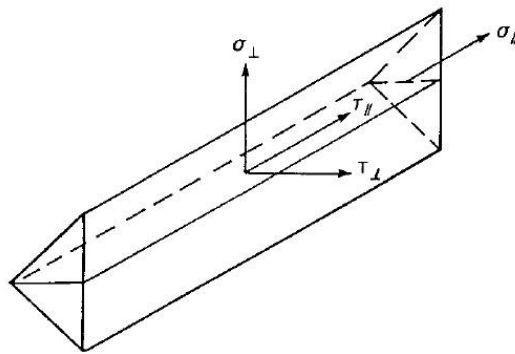
$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ Mpa}$$

327,60 Mpa < 435.55 Mpa → Uvjet zadovoljen

### 5.2.3 Proračun vara između pločica P2 i P3 direktnom metodom

a=4 mm –debljina vara

L=320 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{116\,310}{4 \cdot 320} = 115,39 \text{ MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80 \text{ MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{20\,680 \cdot 51\,200}{19\,114\,667 \cdot 4} = 13,85 \text{ Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{4 \cdot 320^3}{12} = 19\,114\,667 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = \frac{320}{2} \cdot 4 \cdot \frac{320}{4} = 51\,200 \text{ mm}^3 \text{ – statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{147\,700 \cdot 640}{1\,706,67 \cdot 320} = 173,09 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{320 \cdot 4^3}{12} = 1\,706,67 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = 320 \cdot 2 \cdot 1 = 640 \text{ mm}^3 \text{ – statički moment površine}$$

2.uvjet:

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$



$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{4} = \frac{[115,39^2 + 3(173,09^2 + 13,85^2)]^{0.5}}{4} = 80,53 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ MPa}$$

80,53 Mpa < 435,55 Mpa → Uvjet zadovoljen

#### 5.2.4 Spoj grede s pločicama P10 vijcima M20

Spoj je dvorezan s debelim pločama kao vanjskim elementima ( $t_{PL} > d_{spajala}$ )

$a = 4d = 4 \cdot 20 = 80 \text{ mm}$  – minimalni razmak vijaka u smjeru okomitom na vlakanca grede

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0,3 \cdot f_{uk} \cdot d^{2,6} = 0,3 \cdot 490 \cdot 20^{2,6} = 354\,810 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1,1} = 322\,555 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$$f_{h,0,k} = 0,082 \cdot (1 - 0,01 \cdot d) \cdot \rho_k = 0,082 \cdot (1 - 0,01 \cdot 20) \cdot 380 = 24,93 \text{ N/mm}^2$$

$$k_{90} = 0,9 + 0,015 \cdot d = 0,9 + 0,015 \cdot 20 = 1,20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0,90 \cdot \frac{20,78}{1,25} = 14,96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{l} 0,5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0,5 \cdot (14,96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2,3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2,3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14,96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943 \text{ N} \end{array} \right\}$$

$$R_d = 29,92 \text{ kN}$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{44,70}{6} = 7,45 \text{ kN}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{116,31}{6} = 19,38 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{19,38^2 + 7,45^2} = 20,77 \text{ kN}$$

$$R_d = 29,92 \text{ kN} < F_d = 20,77 \text{ kN}$$

→Uvjet zadovoljen

$$\eta = \frac{20,77}{29,92} = 0,69$$

### 5.3 VLAČNI NASTAVAK GREDE (pločice i vijci)

Rezne sile:  $V_{Ed} = 76,66$ ,  $N_{Ed} = 155,89$  kN

Kvaliteta materijala:

Vijci : kv.5.8;  $f_{yk} = 400$  MPa ;  $f_{uk} = 500$  MPa

Drvo: LLD GL24h  $\rightarrow \rho_k = 380$  kg/m<sup>3</sup>  $\rightarrow \gamma_M = 1,25$

Uporabna klasa 2.  $\rightarrow$  kratko opterećenje  $\rightarrow k_{mod} = 0,90$

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

$d = 20$ mm

$a = 4d = 4 \cdot 20 = 80$  mm – minimalni razmak vijaka u smjeru okomitom na vlakanca grede

$t_{min} = 0.3d = 6$ mm

Odabrane dimenzije pločice P14: 480/240/10mm

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0,3 \cdot f_{uk} \cdot d^{2,6} = 0,3 \cdot 490 \cdot 20^{2,6} = 354\,810 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1,1} = 322\,555 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$$f_{h,0,k} = 0,082 \cdot (1 - 0,01 \cdot d) \cdot \rho_k = 0,082 \cdot (1 - 0,01 \cdot 20) \cdot 380 = 24,93 \text{ N/mm}^2$$

$$k_{90} = 0,9 + 0,015 \cdot d = 0,9 + 0,015 \cdot 20 = 1,20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0,90 \cdot \frac{20,78}{1,25} = 14,96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{l} 0,5 \cdot (f_{h,\alpha,d} \cdot t \cdot d) = 0,5 \cdot (14,96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2,3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2,3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14,96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943 \text{ N} \end{array} \right.$$

$$R_d = 29,92 \text{ kN}$$

odabrano  $n = 8$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{155,89}{8} = 19,48 \text{ kN}$$

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{76,66}{8} = 9,58 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{19,48^2 + 9,58^2} = 21,71 \text{ kN}$$

$$R_d = 29,92 \text{ kN} < F_d = 21,71 \text{ kN}$$

→Uvjet zadovoljen

$$\eta = \frac{21,71}{29,92} = 0,73$$

## 5.4 SPOJ STUP – ZATEGA

Rezne sile:  $N_{Ed} = 60,82 \text{ kN}$

Kvaliteta materijala:

Vijci : kv.5.8;  $f_{yk} = 400 \text{ MPa}$  ;  $f_{uk} = 500 \text{ MPa}$

Drvo: LLD GL24h  $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

Uporabna klasa 2.  $\rightarrow$  kratko opterećenje  $\rightarrow k_{mod} = 0,90$

### 5.4.1 Proračun vijaka i pločica na stupu:

Spoj je dvorezan s čeličnim pločicama kao vanjskim elementima .

$d = 20 \text{ mm}$

$a = 4d = 4 \cdot 20 = 80 \text{ mm}$  – minimalni razmak vijaka u smjeru okomitom na vlakanca

Odabrane dimenzije pločice: 320/320/8mm

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0,3 \cdot f_{uk} \cdot d^{2,6} = 0,3 \cdot 490 \cdot 20^{2,6} = 354\,810 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{354\,810}{1,1} = 322\,555 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$$f_{h,0,k} = 0,082 \cdot (1 - 0,01 \cdot d) \cdot \rho_k = 0,082 \cdot (1 - 0,01 \cdot 20) \cdot 380 = 24,93 \text{ N/mm}^2$$

$$k_{90} = 0,9 + 0,015 \cdot d = 0,9 + 0,015 \cdot 20 = 1,20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0,90 \cdot \frac{20,78}{1,25} = 14,96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{l} 0,5 \cdot (f_{h,\alpha,d} \cdot t \cdot d) = 0,5 \cdot (14,96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2,3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2,3 \cdot \sqrt{2 \cdot 322\,555 \cdot 14,96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 31\,954 + \frac{F_{ax}}{4} = 31\,954 + \frac{31\,954}{4} = 39\,943 \text{ N} \end{array} \right.$$

$$R_d = 29,92 \text{ kN}$$

odabrano  $n = 6$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{60,82}{6} = 10,14 \text{ kN}$$

$$R_d = 29,92 \text{ kN} \geq F_d = 10,14 \text{ kN}$$

→Uvjet zadovoljen

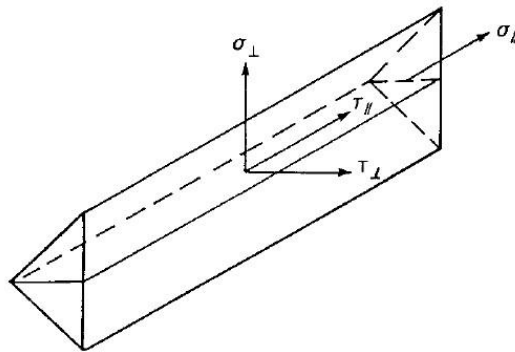
$$\eta = \frac{10,14}{29,92} = 0,34$$

#### 5.4.2 Proračun vara između pločica P11 i P12 direktnom metodom

Dimenzije pločice P12: 320/184/10mm

a=4 mm –debljina vara

L=100 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{60\,820}{4 \cdot 100} = 152,05 \text{ MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80 \text{ MPa}$$

→Uvjet zadovoljen

$$I = \frac{b \cdot h^3}{12} = \frac{4 \cdot 100^3}{12} = 333\,333 \text{ mm}^4 - \text{moment tromosti}$$

$$S = \frac{100}{2} \cdot 4 \cdot \frac{100}{4} = 5\,000 \text{ mm}^3 - \text{statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{60\,820 \cdot 300}{533,33 \cdot 100} = 342,11 \text{ MPa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{100 \cdot 4^3}{12} = 533,33 \text{ mm}^4 - \text{moment tromosti}$$

$$S = 100 \cdot 2 \cdot 1,5 = 300 \text{ mm}^3 - \text{statički moment površine}$$

2.uvjet:

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} = \frac{[152,05^2 + 3(342,11^2)]^{0.5}}{2} = 305,87 \text{ MPa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ MPa}$$

$305,87 \text{ Mpa} < 435,55 \text{ Mpa} \rightarrow \text{Uvjet zadovoljen}$

Napomena: istim se varom spaja i pločica P13 sa zategom.

#### 5.4.3 Proračun vijaka na spoju pločica P12 i P13 (spoj čelik – čelik)

Odabrano:  $d = 16 \text{ mm}$ ,  $n = 2$

Preporučeni razmaci vijaka za odabrani promjer i debljinu lima  $t = 10 \text{ mm}$ :

$e_1 = 40 \text{ mm} \rightarrow \text{udaljenost od kraja lima}$

$p_1 = p_2 = 55 \text{ mm} \rightarrow \text{međusobna udaljenost vijaka}$

$e_2 = 30 \text{ mm} \rightarrow \text{udaljenost od ruba lima}$

Odabrane dimenzije pločice:  $285/70/10 \text{ mm}$

Otpornost vijka na posmik:  $F_{t,Rk} = \alpha \cdot f_{uk} \cdot A_S = 0,6 \cdot 500 \cdot 157 = 47,1 \text{ kN}$

$$F_{t,Rd} = \frac{47,1}{1,25} = 37,68 \text{ kN}$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{60,82}{2} = 30,41 \text{ kN}$$

$$F_{t,Rd} = 37,68 \text{ kN} \geq F_d = 30,41 \text{ kN}$$

$\rightarrow \text{Uvjet zadovoljen}$

$$\eta = \frac{30,41}{37,68} = 0,81$$

## 5.5 SPOJ STUP-TEMELJ

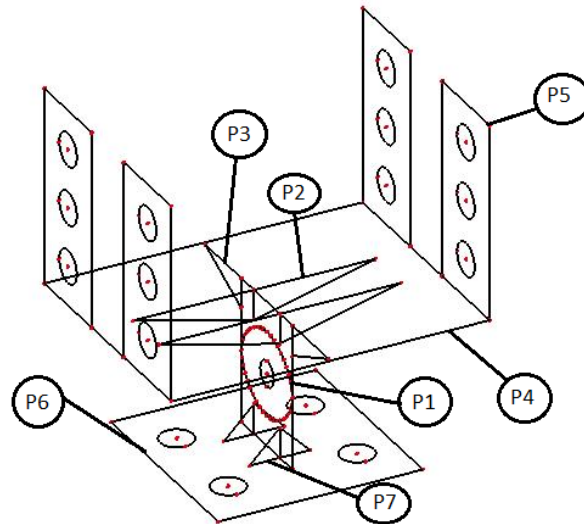
Rezne sile:  $V_{Ed} = 56,68 \text{ kN}$ ,  $N_{Ed} = 157,63 \text{ kN}$

Kvaliteta materijala:

Trnovi i vijci : kv.5.8;  $f_{yk} = 400 \text{ MPa}$  ;  $f_{uk} = 500 \text{ MPa}$

Drvo: LLD GL24h  $\rightarrow \rho_k = 380 \text{ kg/m}^3 \rightarrow \gamma_M = 1,25$

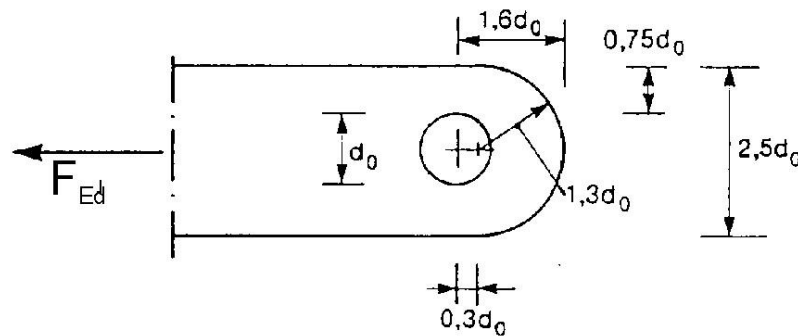
Uporabna klasa 2.  $\rightarrow$  kratko opterećenje  $\rightarrow k_{mod} = 0,90$



Prikaz modela s oznakama pločica

### 5.5.1 Proračun trna i debljine pločica P1 na zglobu

$d_{odabrano} = 32 \text{ mm}$  –promjer trna



Preporučene dimenzije za P1 prema Eurokodu 3

Dimenzije pločice odabiru se prema preporukama sa slike 6.1.2.

Geometrijski uvjeti:

$$1. \quad t \geq 0,7 \cdot \sqrt{\frac{F_{Ed} \cdot \gamma_{M0}}{f_y}} = 0,7 \cdot \sqrt{\frac{157\,630 \cdot 1,0}{355}} = 14,75 \text{ mm}$$

$$2. \quad d_0 \leq 2,5 \cdot t$$

$$33 \text{ mm} \leq 2,5 \cdot 18 = 45 \text{ mm}$$

$\rightarrow$  Uvjeti zadovoljeni  $\rightarrow$  odabrana debljina pločice  $t=18 \text{ mm}$

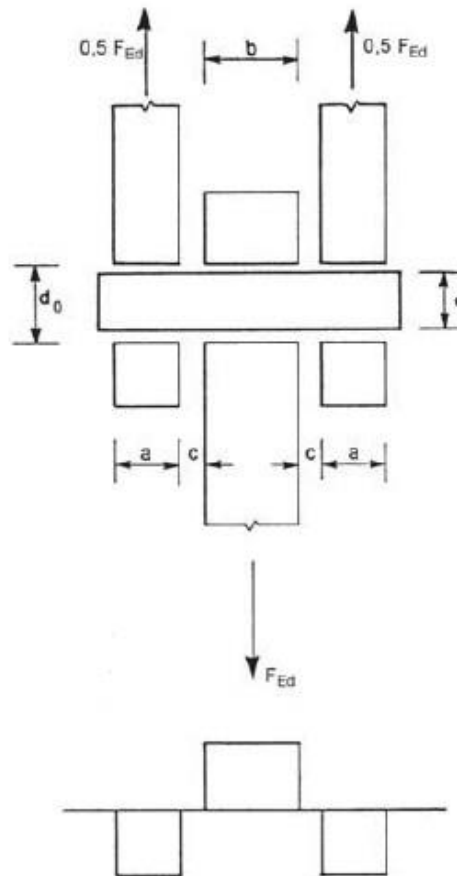


Otpornost trna savijanje:

$$M_{b,Rd} = \frac{1,5 \cdot W_{el} \cdot f_y}{\gamma_{M0}} = \frac{1,5 \cdot 3149,60 \cdot 400}{1,0} = 1\,889\,760 \text{ Nmm}$$

$$M_{Ed} = \frac{F_{Ed}}{8} \cdot (b + 4c + 2a) = \frac{157\,630}{8} \cdot (18 + 20 + 36) = 1\,458\,078 \text{ Nmm}$$

Napomena: Moment savijanja izračunat je prema shemi sa slike



$$M_{Ed} = \frac{F_{Ed}}{8} (b + 4c + 2a)$$

*Moment savijanja u spajalu*

$$M_{b,Rd} = 1,89 \text{ kNm} > M_{Ed} = 1,46 \text{ kNm}$$

→Uvjet zadovoljen

Posmična otpornost trna:

$$F_{V,Rd} = \frac{0,6 \cdot A \cdot f_{up}}{\gamma_{M2}} = \frac{0,6 \cdot 804 \cdot 490}{1,25} = 189\,100 \text{ N} = 189,10 \text{ kN}$$

$$F_{V,Ed} = 56,68 \text{ kN}$$

$$F_{V,Rd} > F_{V,Ed} \rightarrow \text{Uvjet zadovoljen}$$

Interakcija M+V:

$$\left(\frac{M_{Ed}}{M_{Rd}}\right)^2 + \left(\frac{F_{V,Ed}}{F_{V,Rd}}\right)^2 \leq 1$$

$$\left(\frac{1,46}{1,89}\right)^2 + \left(\frac{56,68}{189,10}\right)^2 \leq 1$$

$$0,69 \leq 1$$

Pritisak po omotaču rupe:

$$F_{b,Rd} = \frac{1,5 \cdot t \cdot d \cdot f_y}{\gamma_{M0}} = \frac{1,5 \cdot 18 \cdot 32 \cdot 355}{1,0} = 306\,720 \text{ N} = 306,72 \text{ kN}$$

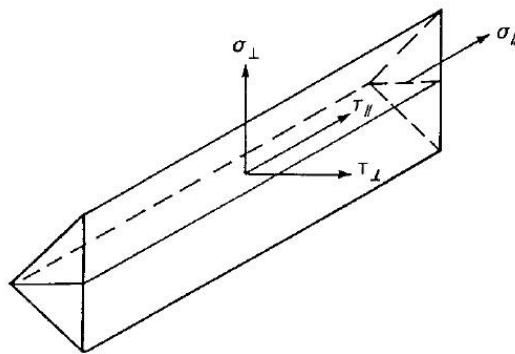
$$F_{b,Ed} = 157,63 \text{ kN}$$

$$F_{b,Rd} > F_{b,Ed} \rightarrow \text{Uvjet zadovoljen}$$

### 5.5.2 Proračun vara između pločica P1 i P4 direktnom metodom

a=7 mm –debljina vara

L=130 mm –duljina vara



1.uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{157\,630}{7 \cdot 130} = 173,22 \text{ MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80 \text{ MPa}$$

→Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{56\,680 \cdot 14\,788}{1\,281\,583 \cdot 7} = 93,43 \text{ MPa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{7 \cdot 130^3}{12} = 1\,281\,583 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = \frac{130}{2} \cdot 7 \cdot \frac{130}{4} = 14\,788 \text{ mm}^3 \text{ – statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{157\,630 \cdot 796,30}{3\,716 \cdot 130} = 259,83 \text{ MPa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{130 \cdot 7^3}{12} = 3\,716 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = 130 \cdot 3,5 \cdot 1,75 = 796,30 \text{ mm}^3 \text{ – statički moment površine}$$

2. uvjet:

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} = \frac{[173,22^2 + 3(259,83^2 + 93,43^2)]^{0.5}}{2} = 254,33 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ MPa}$$

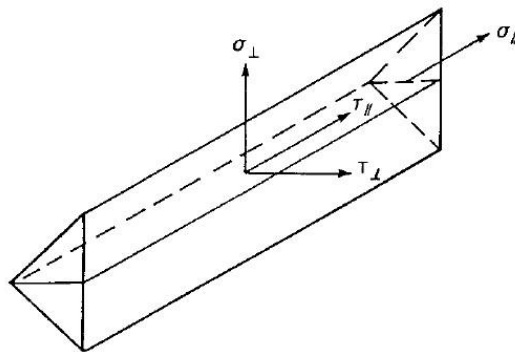
254,33 Mpa < 435,55 Mpa → Uvjet zadovoljen

Napomena: isti var se nalazi između pločica P1 i P5.

### 5.5.3 Proračun vara između pločica P3 i P4 direktnom metodom

a=6 mm – debljina vara

L=120 mm – duljina vara



1. uvjet:

$$\sigma_{\perp} = \frac{N_{Ed}}{A} = \frac{157\,630}{6 \cdot 120} = 218,93 \text{ MPa} < 0,9 \cdot \frac{f_u}{\gamma_{M2}} = 0,9 \cdot \frac{490}{1,25} = 352,80 \text{ MPa}$$

→ Uvjet zadovoljen

$$\tau_{\parallel} = \frac{V_{Ed} \cdot S}{I \cdot b} = \frac{56\,680 \cdot 10\,800}{864\,000 \cdot 6} = 118,08 \text{ Mpa}$$

$$I = \frac{b \cdot h^3}{12} = \frac{6 \cdot 120^3}{12} = 864\,000 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = \frac{120}{2} \cdot 6 \cdot \frac{120}{4} = 10\,800 \text{ mm}^3 \text{ – statički moment površine}$$

$$\tau_{\perp} = \frac{N_{Ed} \cdot S}{I \cdot h} = \frac{157\,630 \cdot 540}{2\,160 \cdot 120} = 328,40 \text{ Mpa}$$

$$I = \frac{h \cdot b^3}{12} = \frac{120 \cdot 6^3}{12} = 2\,160 \text{ mm}^4 \text{ – moment tromosti}$$

$$S = 120 \cdot 3 \cdot 1,5 = 540 \text{ mm}^3 \text{ – statički moment površine}$$

2. uvjet:

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} \leq \frac{f_u}{\beta \cdot \gamma_{M2}}$$

$$\frac{[\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5}}{2} = \frac{[218,93^2 + 3(328,4^2 + 118,08^2)]^{0.5}}{2} = 321,44 \text{ Mpa}$$

$$\frac{f_u}{\beta \cdot \gamma_{M2}} = \frac{490}{0,9 \cdot 1,25} = 435,55 \text{ MPa}$$

321,44 Mpa < 435,55 Mpa → Uvjet zadovoljen

#### 5.5.4 Spoj stupa s pločicama P5 vijcima d = 20 mm

Spoj je dvorezan s debelim pločama kao vanjskim elementima ( $t_{PL} > d_{spajala}$ )  
 $a = 4d = 4 \cdot 20 = 80 \text{ mm}$  – minimalni razmak trnova u smjeru okomitom na vlakanca grede.

Karakteristični moment tečenja spajala:

$$M_{y,Rk} = 0,3 \cdot f_{uk} \cdot d^{2,6} = 0,3 \cdot 500 \cdot 20^{2,6} = 362\,051 \text{ Nmm}$$

Proračunska vrijednost momenta tečenja spajala:

$$M_{y,Rd} = \frac{M_{y,Rk}}{\gamma_M} = \frac{362\,051}{1,1} = 329\,137 \text{ Nmm}$$

Karakteristična čvrstoća po omotaču rupe kada opterećenje djeluje u pravcu vlakana :

$$f_{h,0,k} = 0,082 \cdot (1 - 0,01 \cdot d) \cdot \rho_k = 0,082 \cdot (1 - 0,01 \cdot 20) \cdot 380 = 24,93 \text{ N/mm}^2$$

$$k_{90} = 0,9 + 0,015 \cdot d = 0,9 + 0,015 \cdot 20 = 1,20$$

Karakteristična čvrstoća po omotaču rupe osnovnog materijala :

$$\alpha = 90^\circ$$

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = \frac{24,93}{1,2 \cdot \sin^2 90 + \cos^2 90} = 20,78 \text{ N/mm}^2$$

Proračunska čvrstoća po omotaču rupe osnovnog materijala :

$$f_{h,\alpha,d} = k_{mod} \cdot \frac{f_{h,\alpha,k}}{\gamma_M} = 0,90 \cdot \frac{20,78}{1,25} = 14,96 \text{ N/mm}^2$$

Proračunska otpornost jednog vijka:

$$R_d = \min \left\{ \begin{array}{l} 0,5 \cdot (f_{h,\alpha,d} \cdot t_2 \cdot d) = 0,5 \cdot (14,96 \cdot 200 \cdot 20) = 29\,920 \text{ N} \\ 2,3 \cdot \sqrt{2 \cdot M_{y,Rd} \cdot f_{h,\alpha,d} \cdot d} + \frac{F_{ax}}{4} = 2,3 \cdot \sqrt{2 \cdot 329\,137 \cdot 14,96 \cdot 20} + \frac{F_{ax}}{4} = \\ = 32\,278 + \frac{F_{ax}}{4} = 32\,278 + \frac{32\,278}{4} = 40\,348 \text{ N} \end{array} \right.$$

$$R_d = 29,92 \text{ kN}$$

Doprinos jednog vijka u prihvaćanju unutrašnjih sila:

-od poprečne sile:

$$F_{Vd} = \frac{V_{Ed}}{n} = \frac{56,68}{8} = 7,09 \text{ Kn}$$

-od uzdužne sile:

$$F_{Nd} = \frac{N_{Ed}}{n} = \frac{157,63}{8} = 19,7 \text{ kN}$$

Proračunska vrijednost sile koju preuzima 1 vijak:

$$F_d = \sqrt{F_N^2 + F_V^2}$$

$$F_d = \sqrt{7,09^2 + 19,7^2} = 20,93 \text{ kN}$$

$$R_d = 29,92 \text{ kN} > F_d = 20,93 \text{ kN}$$

→Uvjet zadovoljen

$$\eta = \frac{20,93}{29,92} = 0,70$$

Naprezanja na stupu preko pločice P5:

$$f_{b,Ed} \leq k_{mod} \cdot \frac{f_{c,0,k}}{\gamma_M}$$

$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{157 \cdot 630}{460 \cdot 20} = 17,13 \text{ Mpa} < 0,90 \cdot \frac{24}{1,25} = 17,28 \text{ Mpa}$$

→ Uvjet zadovoljen

#### 5.5.5 Proračun sidrenih vijaka za spoj s temeljom preko pločice P6

Vijci M20 kv.5.8.

Otpornost na trenje između pločice i podložnog morta:

$$F_{f,Rd} = C_{f,Rd} \cdot N_{c,Ed} = 0,20 \cdot 157,63 = 31,53 \text{ kN}$$

Posmična otpornost sidrenog vijka:

$$F_{vb,Rd} = \min \left\{ \begin{array}{l} F_{1,vb,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}} = \frac{0,5 \cdot 500 \cdot 314}{1,25} = 62,80 \text{ kN} \\ F_{2,vb,Rd} = \frac{\alpha_v \cdot f_{ub} \cdot A}{\gamma_{M2}} = \frac{0,32 \cdot 500 \cdot 314}{1,25} = 40,19 \text{ kN} \end{array} \right\}$$

$$\alpha_b = 0,44 - 0,0003 \cdot f_{yb} = 0,44 - 0,0003 \cdot 400 = 0,32$$

Posmična otpornost čelične pločice:

$$F_{V,Rd} = F_{f,Rd} + n \cdot F_{vb,Rd} = 31,53 + 4 \cdot 40,19 = 192,29 \text{ kN} > F_{V,Ed} = 56,68 \text{ kN}$$

→ Uvjet zadovoljen

Računska čvrstoća prionjivosti vijka:

$$f_{b,d} = 2,25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ct,d} = 2,25 \cdot 1 \cdot 1 \cdot 1 = 2,25 \text{ MPa}$$

$f_{ct,d}$  – vlačna čvrstoća betona

$$f_{ct,d} = \alpha_{CT} \cdot \frac{f_{ctk,05}}{\gamma_c} = 1 \cdot \frac{1,50}{1,5} = 1,50 \text{ MPa}$$

Duljina sidrenja vijaka:

$$l_{b,rqd} = \frac{d}{4} \cdot \frac{\sigma_{Ed}}{f_{bd}} = \frac{20}{4} \cdot \frac{131,57}{2,25} = 292 \text{ mm}$$

$$l_{b,odabrano} = 300 \text{ mm}$$

Naprezanje u 1 vijku:

$$\sigma_{Ed} = \frac{N_{Ed}}{A} = \frac{157\,630}{4 \cdot 314} = 125,50 \text{ Mpa}$$

Usvojene dimenzije pločice P6: 320x320x40 mm

$$f_{b,Ed} \leq \frac{f_{ck}}{\gamma_c}$$

$$f_{b,Ed} = \frac{N_{Ed}}{h \cdot b_{PL}} = \frac{157\,630}{320 \cdot 40} = 12,32 \text{ Mpa} < \frac{20}{1,5} = 13,33 \text{ Mpa}$$

→ Uvjet zadovoljen

*Debljine pločica*

PLOČICA	t <sub>PL</sub> (mm)
P1	18
P2	10
P3	18
P4	26
P5	20
P6	40
P7	10

## 6. PRORAČUN TEMELJA

Proračun dimenzija temelja samca.

Dimenzije temelja: 1500x1500x1000 mm

Dopušteno naprezanje  $\sigma = 500 \text{ Mpa}$

$$N_{sd} = 157,63 \text{ kN (tlak)}$$

$$h = 100 \text{ cm}$$

$$a = \sqrt{\frac{P}{\sigma}} = \sqrt{\frac{157,63}{500}} = 0,56 \text{ m} \Rightarrow \text{odabrano } a = 1,50 \text{ m}$$

Težina temelja:

$$N_t = 1,5 \cdot 1,5 \cdot 1,0 \cdot 25 = 56,25 \text{ [kN]}$$

$$N_{Ed} = N'_{Ed} + N_t = 157,63 + 56,25 = 213,88 \text{ kN (tlak)}$$

Naprezanje ispod temelja:

$$\sigma_{1,2} \leq \sigma_{dop, tla} = 500 \left( \frac{\text{kN}}{\text{m}^2} \right)$$

$$\sigma_{1,2} = \frac{N_{Ed}}{A} \pm \frac{M_{Ed}}{W}$$

$$A = 1,5 \cdot 1,5 = 2,25 \text{ (m}^2\text{)};$$

$$W = \frac{b \cdot a^2}{6} = \frac{1,5^3}{6} = 0,56 \text{ (m}^3\text{)}$$

$$\sigma_{1,2} = \frac{213,88}{2,25}$$

$$\sigma_1 = 95,06 \text{ kN/m}^2 < 500 \text{ kN/m}^2$$

$$\sigma_2 = 95,06 \text{ kN/m}^2 < 500 \text{ kN/m}^2$$

## **7. NACRTI**

7.1 PLAN POZICIJA HALE, M 1:100

7.2 PRESJEK KROZ GLAVNI NOSAČ, M 1:50

7.3 DETALJ „A“: SPOJ STUP-TEMELJ, M 1:10

7.4 DETALJ „B“: SPOJ STUP-GREDA, M 1:10

7.5 DETALJ „C“: ZGLOBNI SPOJ DVIJU GREDA, M 1:10

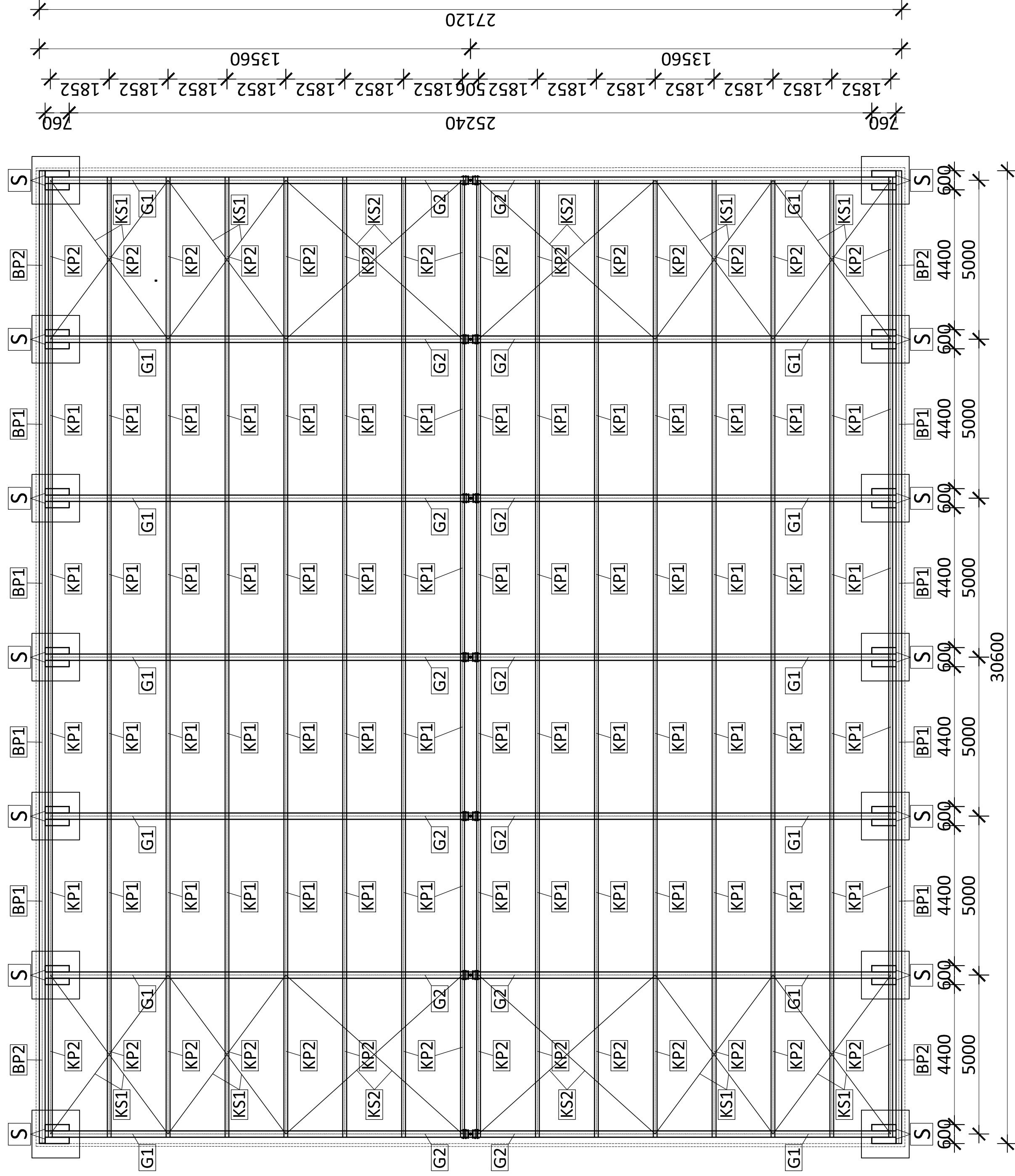
7.6 DETALJ „D“: SPOJ STUP-ZATEGA, M 1:10

7.7 DETALJ „E“: VLAČNI NASTAVAK GREDE, M 1:10

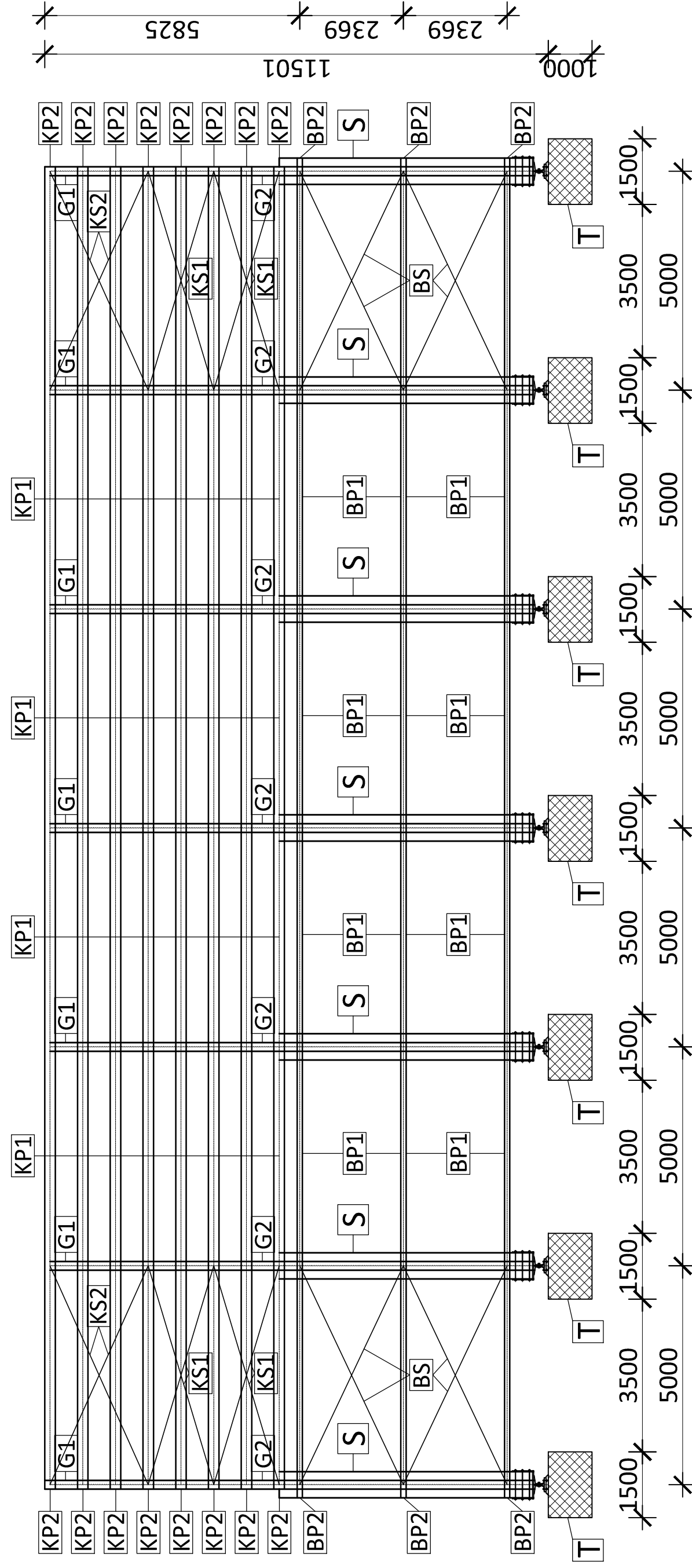
7.8 ISKAZ MATERIJALA, M 1:50



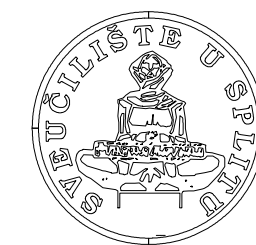
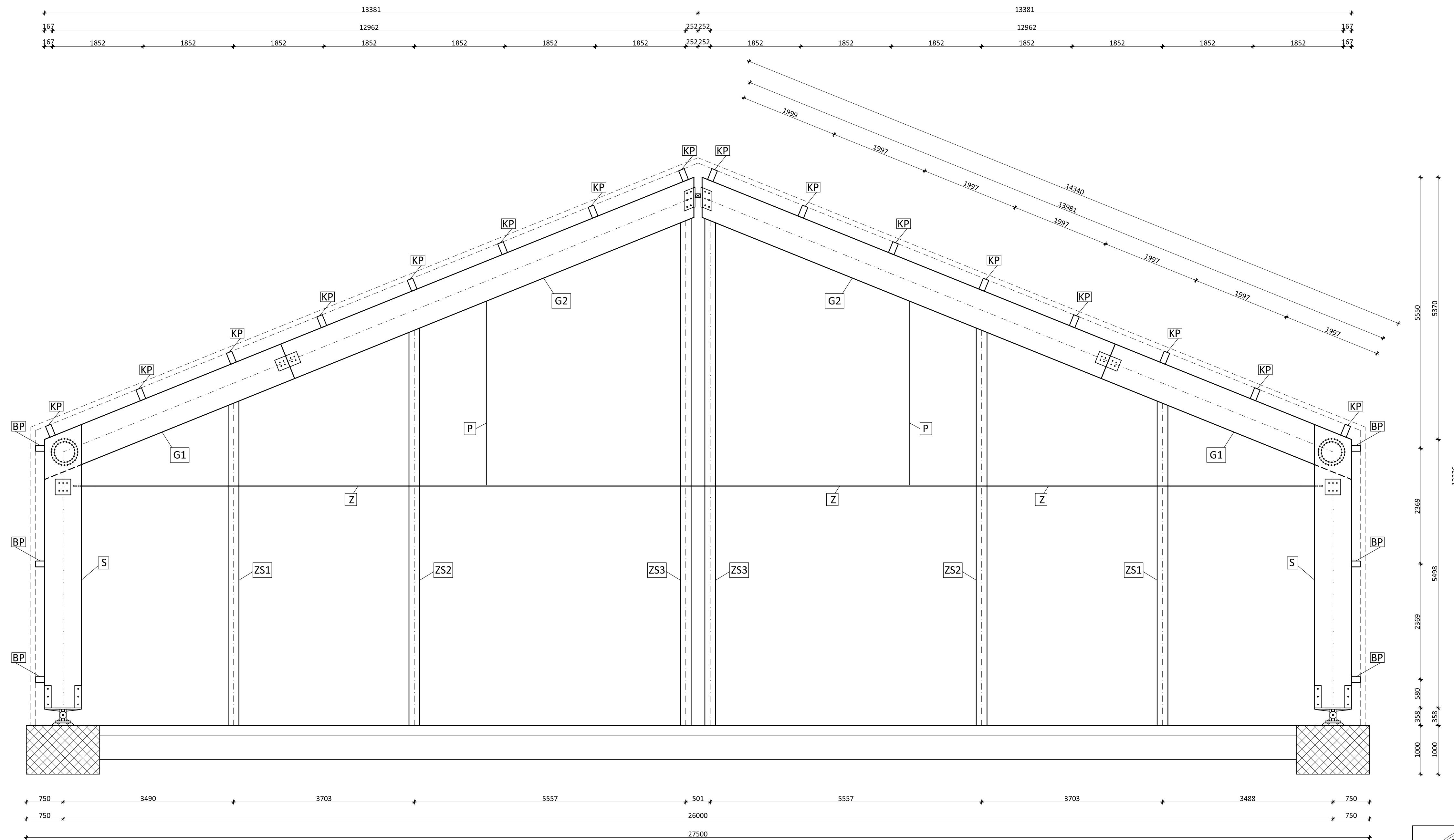
TLOCRT HALE M 1:100



## BOČNI POGLED HALE M 1:100



PRESJEK KROZ GLAVNI NOSAČ  
M 1:50



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE  
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21000 SPLIT, MATICE HRVATSKE 15

KOLEGIJ:	ZAVRŠNI RAD - ODK
----------	-------------------

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

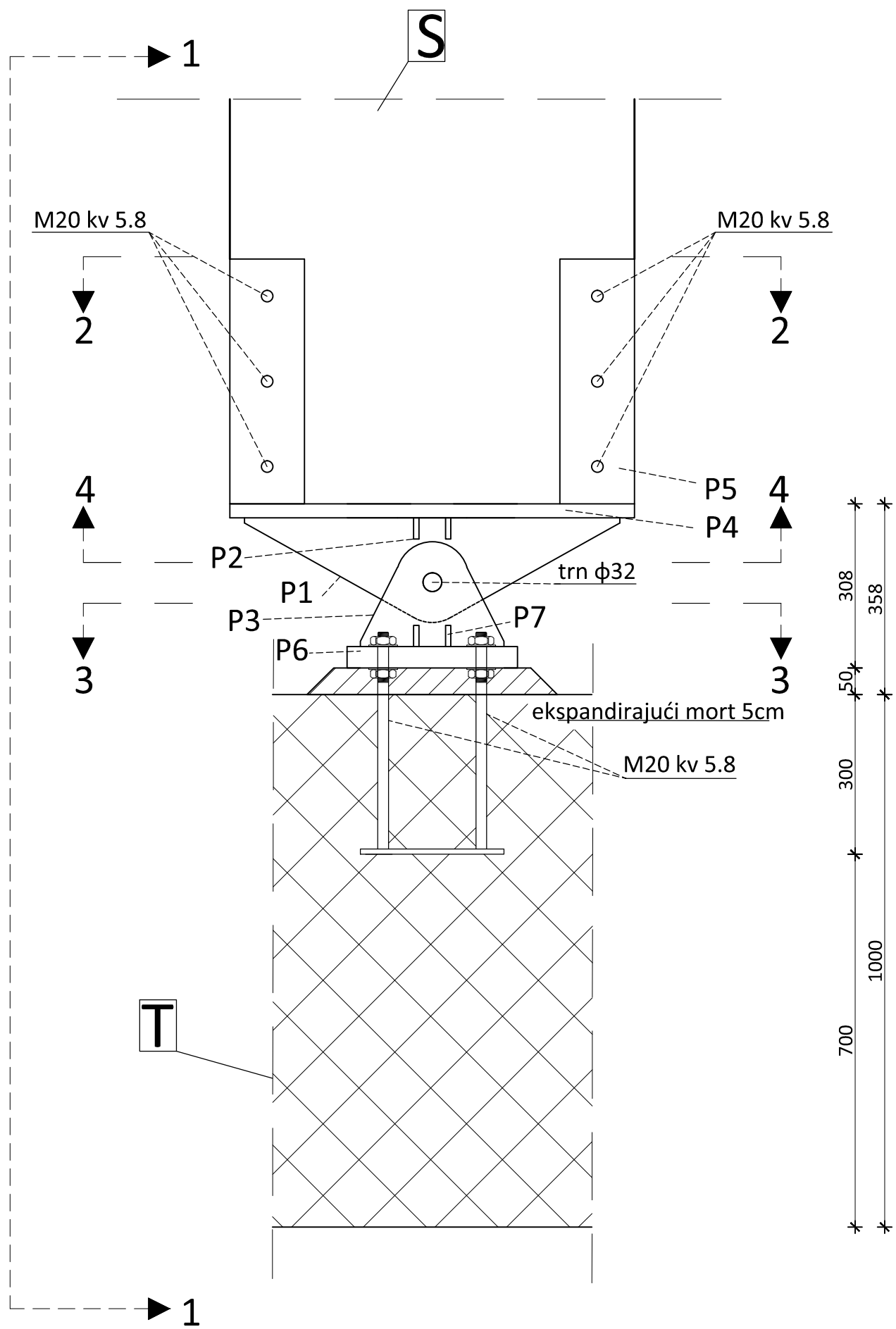
SADRŽAJ PRESJEK KROZ GLAVNI NOSAČ

DATUM:	RUJAN 2018.
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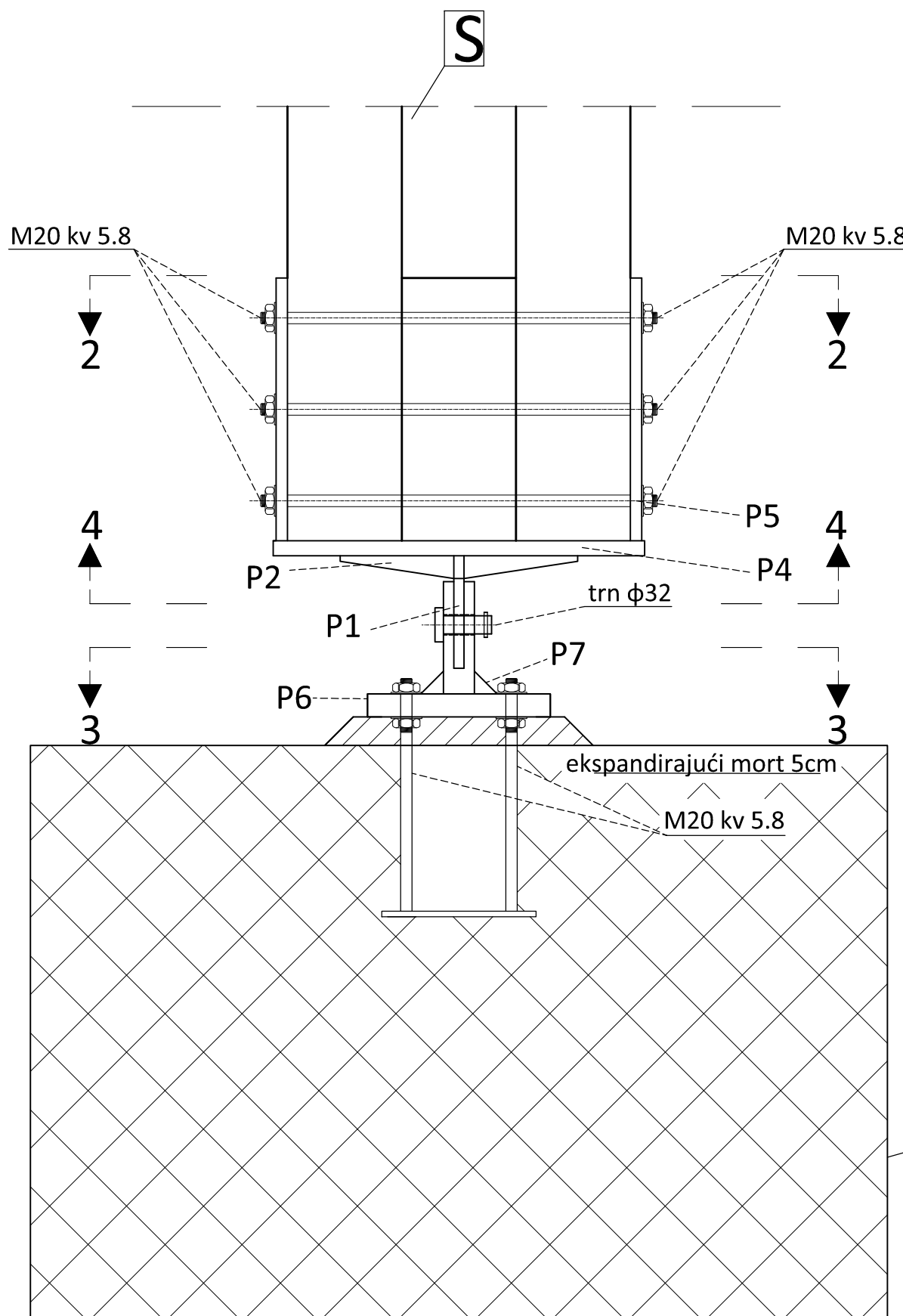
MJERILO: 1:50
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PRILOG:	2
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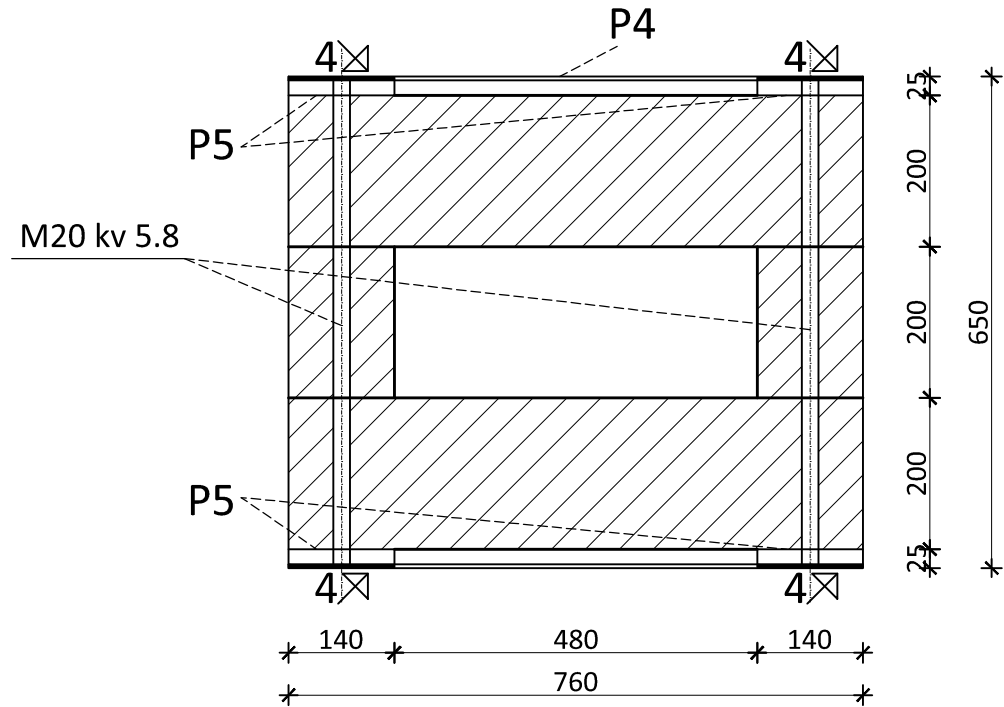
DETALJ "A"



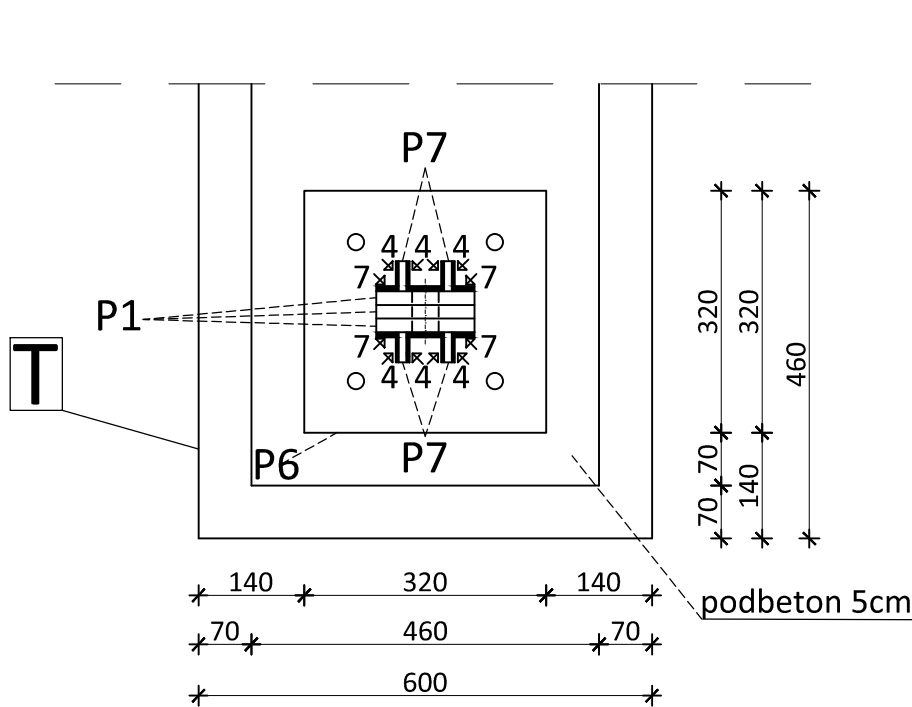
POGLED 1-1



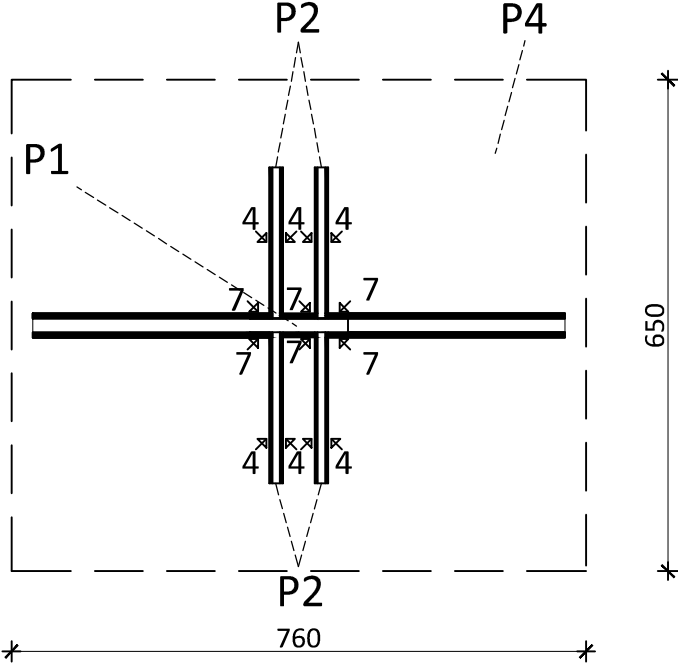
PRESJEK 2-2



PRESJEK 3-3

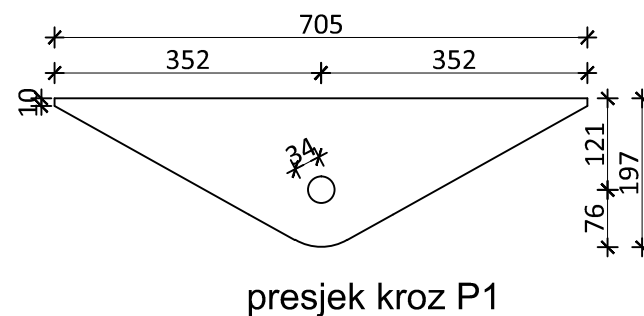


PRESJEK 4-4

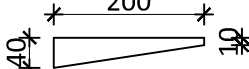


DETALJ "A"  
M 1:10

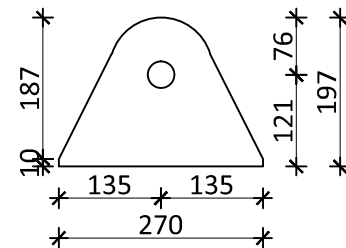
P1 S355 1 kom po spoju



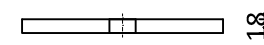
P2 200/40/10 S355  
kom. 4 po spoju



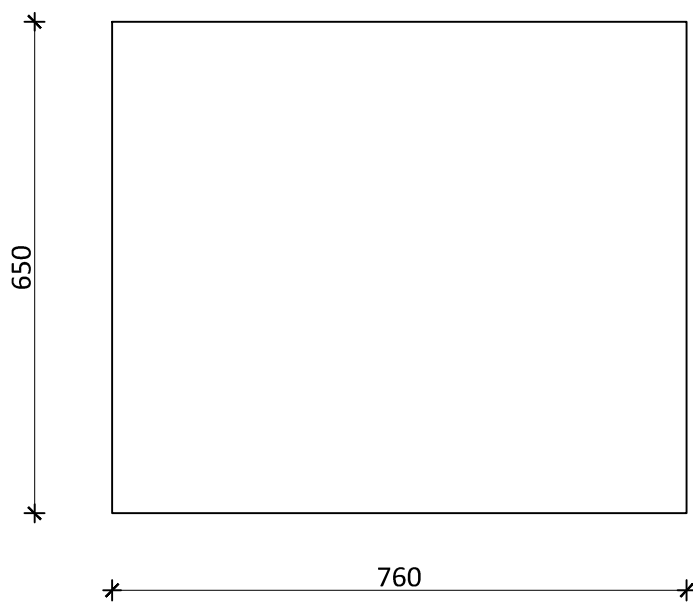
P3 S335 2 kom. po spoju



presjek kroz P1

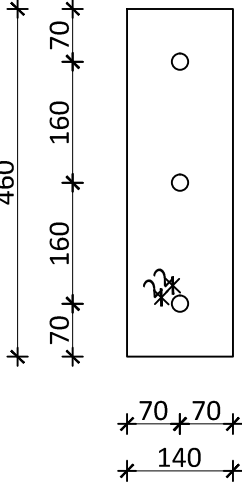


P4 760/620/26 S355  
1 kom. po spoju

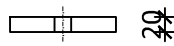


presjek kroz P4

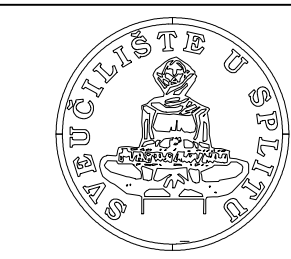
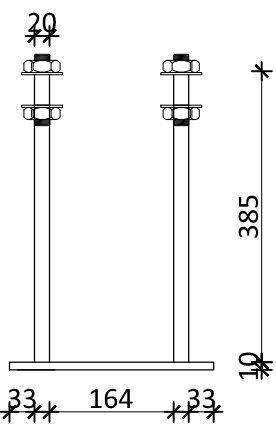
P5 140/460/20 S355  
4 kom. po spoju



presjek kroz P5



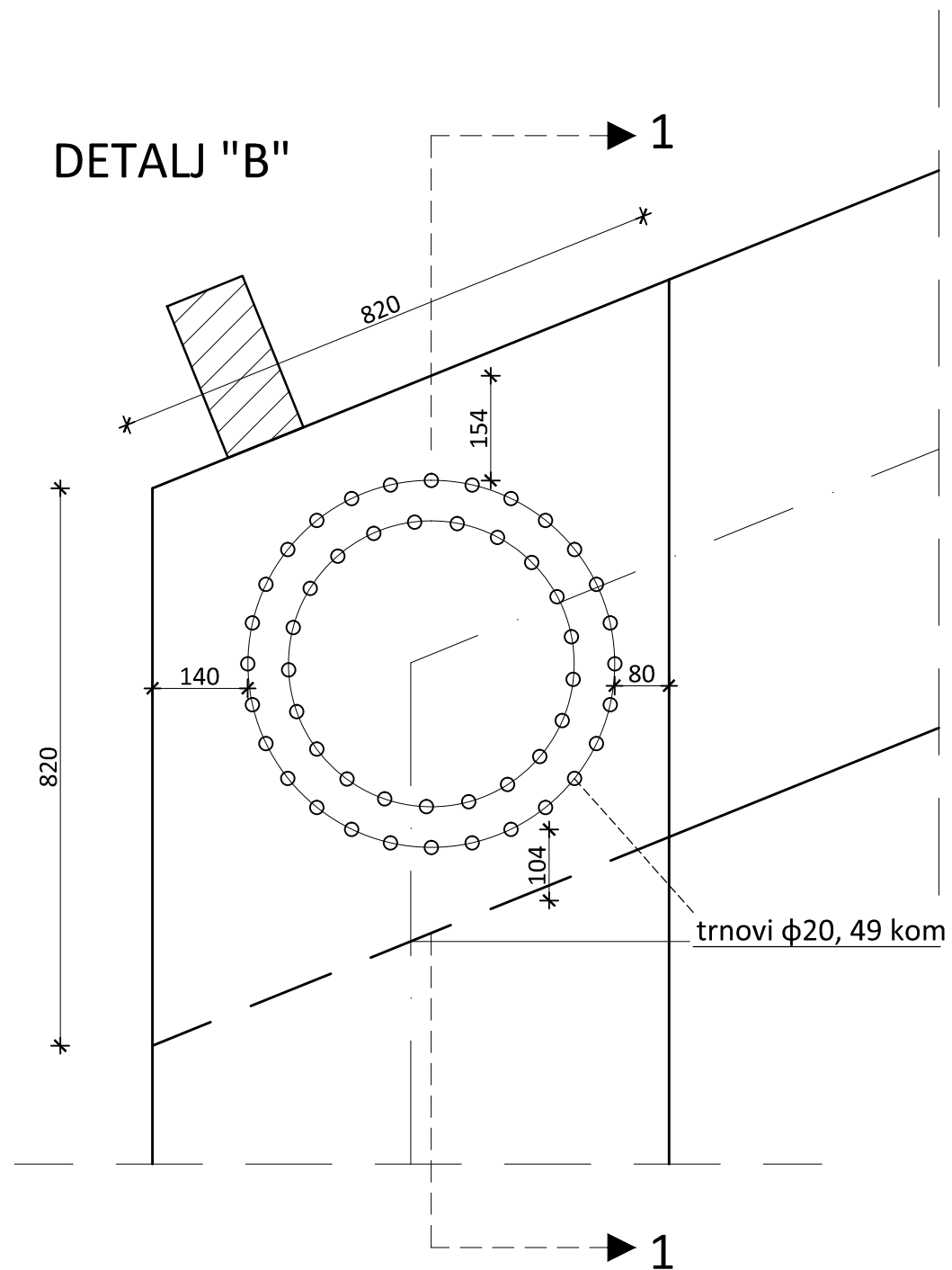
SIDRENI VIJCI M20 kv.5.8



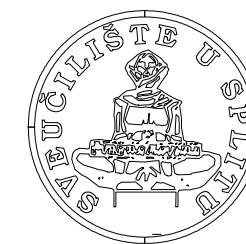
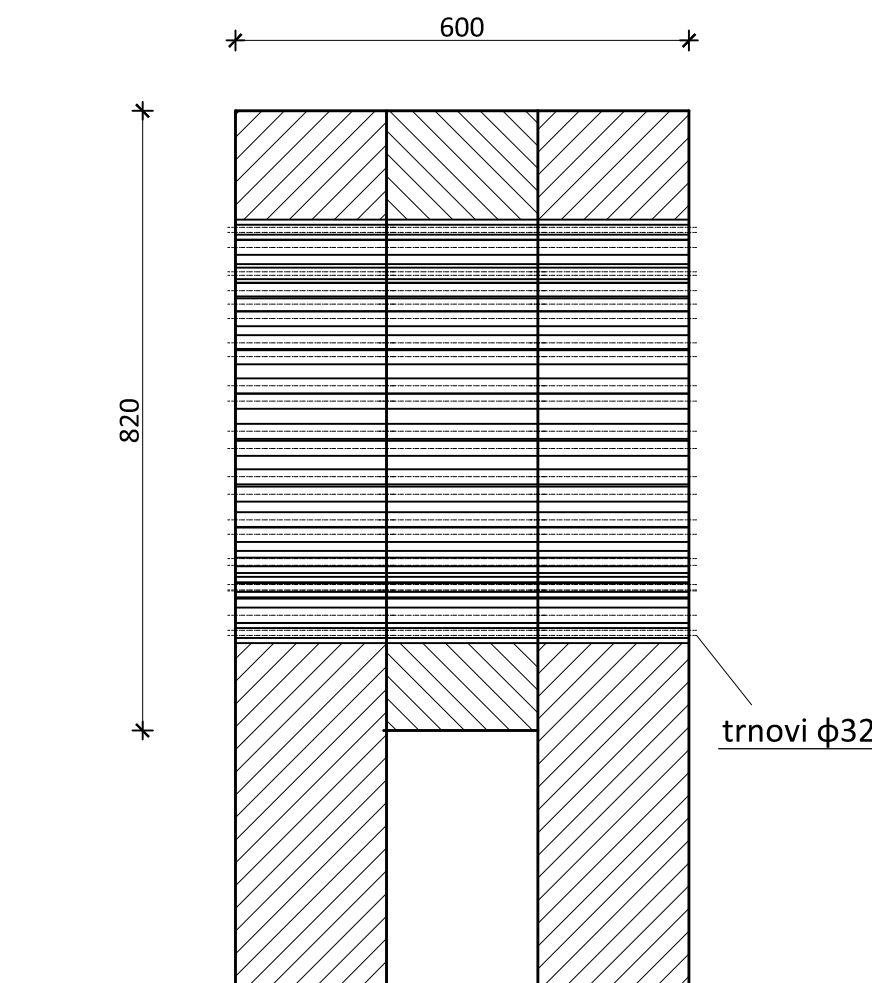
ZAVRŠNI RAD - ODK		
PROGRAM: KONSTRUKCIJA DRVENE HALE		
STUDENT: NIKICA KRALJEVIĆ, 4347		
SAHRŽAJ:	DETALJ "A"	MJERILO: 1:10
RUJAN 2018.		3

# DETALJ "B"

## M 1:10



POGLED 1-1



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ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ:

DETALJ "B"

MJERILO: 1:10

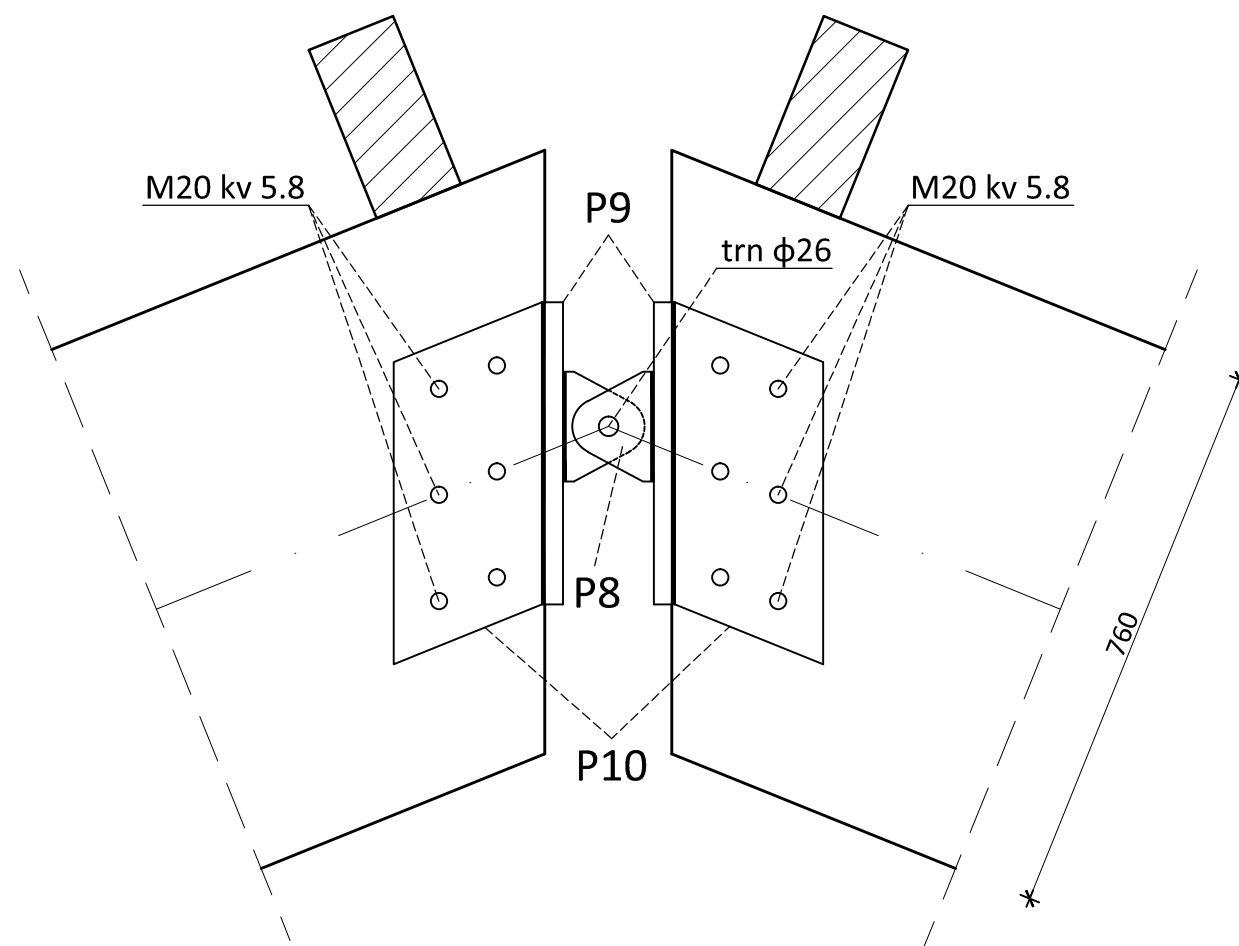
RUJAN 2018.

4

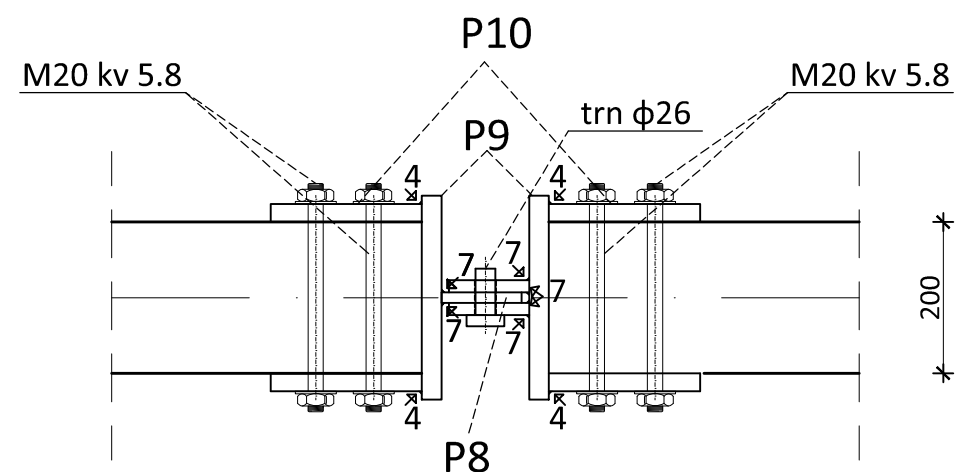
# DETALJ "C"

## M 1:10

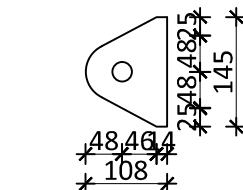
### DETALJ "C"



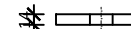
### TLOCRT



**P8** S355 3 kom. po spoju

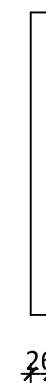
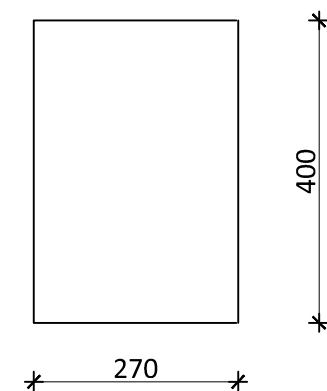


presjek kroz P8



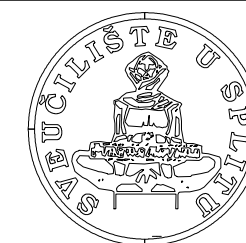
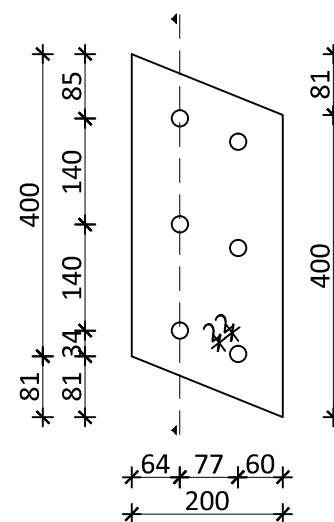
**P9** 270/400/26 S355  
2 kom. po spoju

presjek kroz P9



**P10** 170/400/26 S355  
4 kom. po spoju

presjek kroz P10



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ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ:

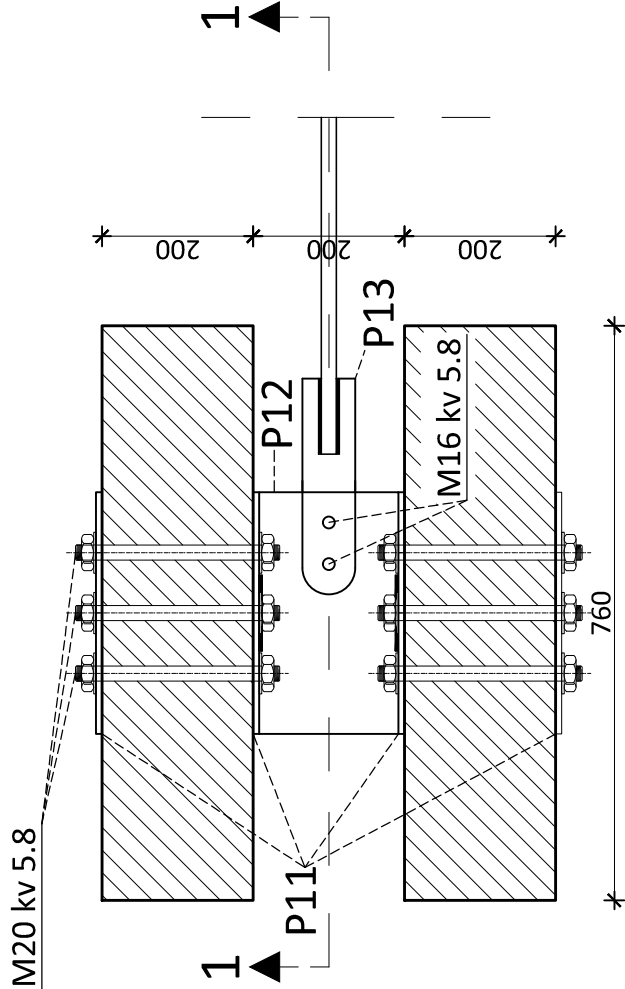
DETALJ "C"

MJERILO: 1:10

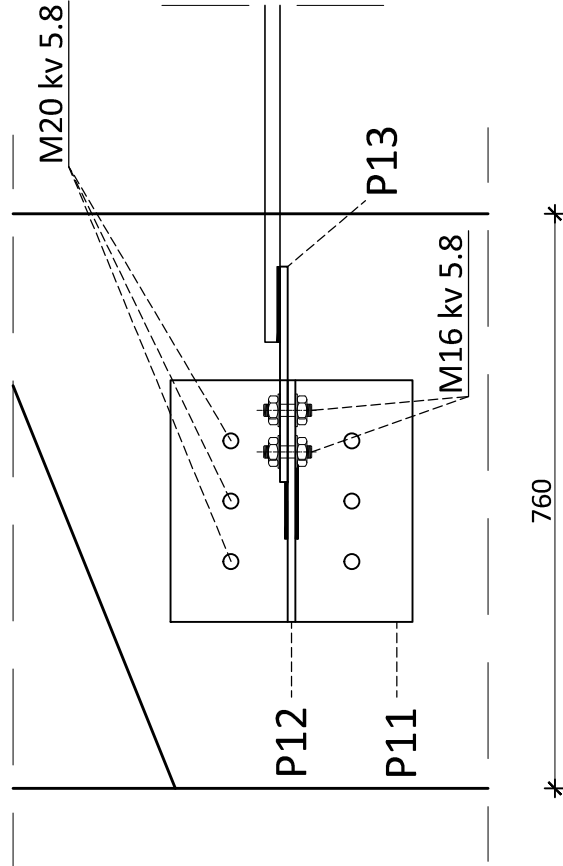
RUJAN 2018.

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DETALJ "D"



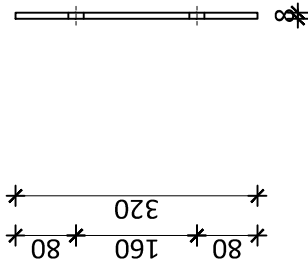
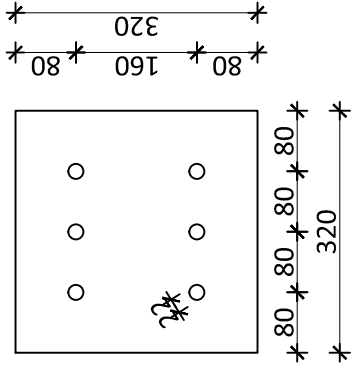
POGLED 1-1



P11

320/320/8 S355  
4 kom. po spoju

presjek kroz P14

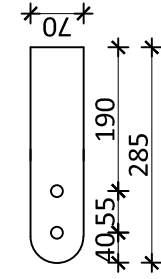
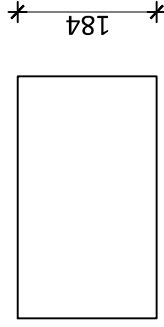


P12

320/184/10 S355  
1 kom. po spoju

P11

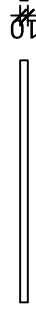
285/70/10 S355  
1 kom. po spoju



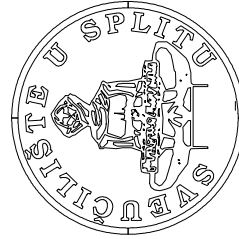
320

presjek kroz P11

presjek kroz P12



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ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

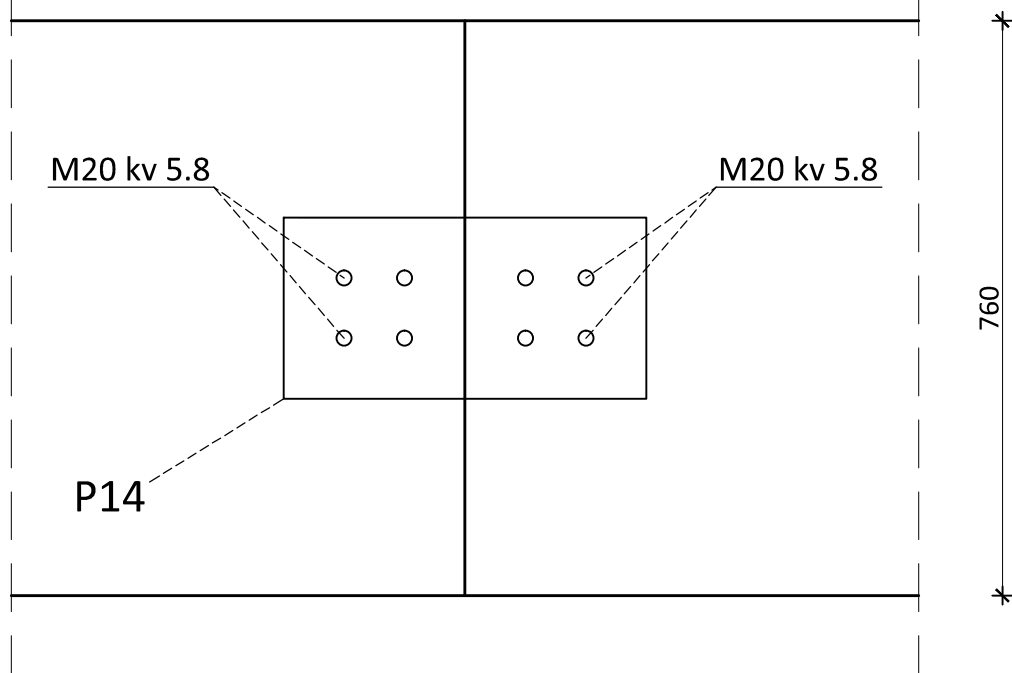
SADRŽAJ: DETALJ "A"

MJERILO: 1:10

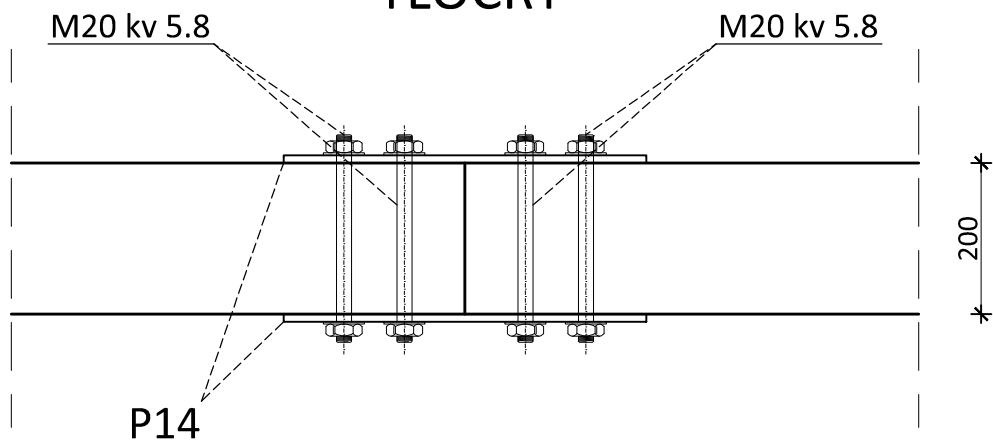
RUJAN 2018.

6

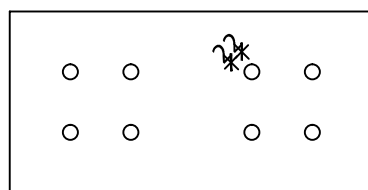
## DETALJ "E"



## TLOCRT



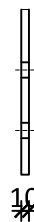
**P14** 480/240/10 S355  
2 kom. po spoju



80 80 160 80 80  
480

80 80 80 80  
240

presjek kroz P14



FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I  
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ZAVRŠNI RAD - ODK

PROGRAM: KONSTRUKCIJA DRVENE HALE

STUDENT: NIKICA KRALJEVIĆ, 4347

SADRŽAJ:

DETALJ "E"

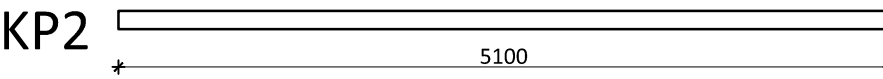
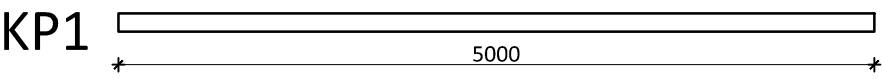
MJERILO: 1:10

RUJAN 2018.

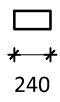
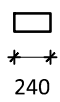
7

ISKAZ MATERIJALA M 1:50

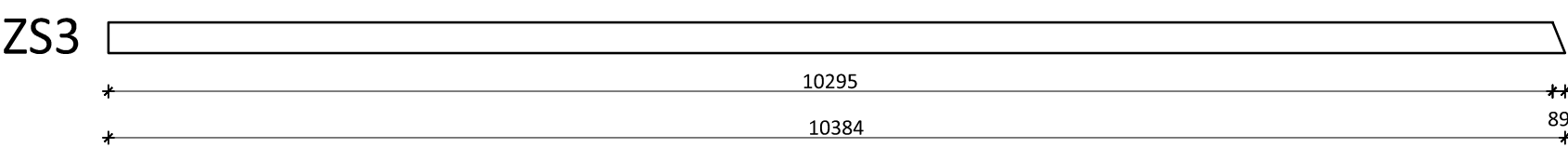
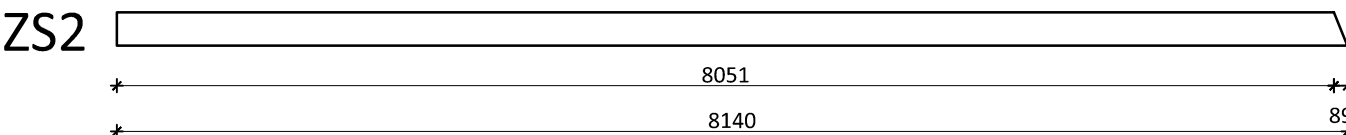
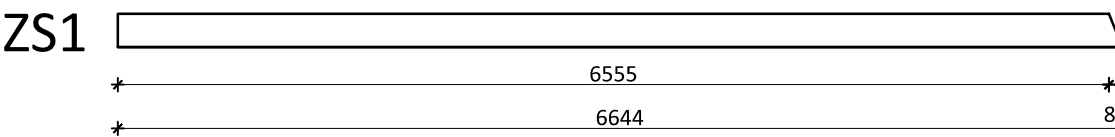
SEKUNDARNI NOSAČI NA KROVU



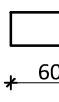
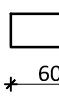
Poprečni presjek



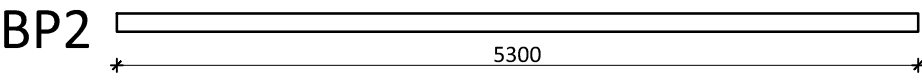
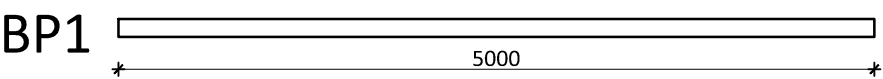
ZABATNI STUP



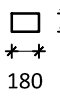
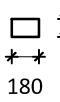
Poprečni presjek



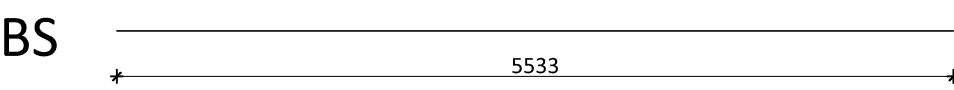
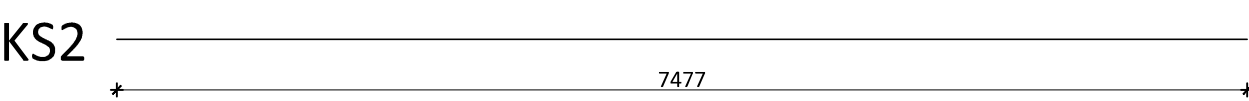
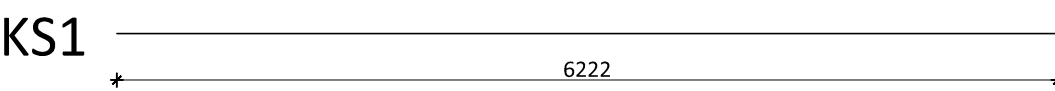
SEKUNDARNI BOČNI NOSAČI



Poprečni presjek



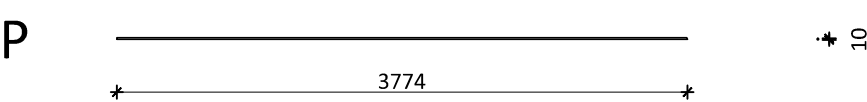
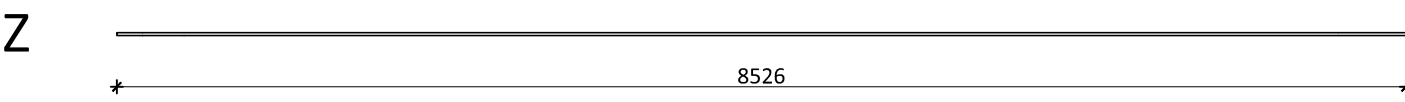
DIJAGONALE SPREGOVA



Poprečni presjek



ZATEGA I PRIDRŽANJE

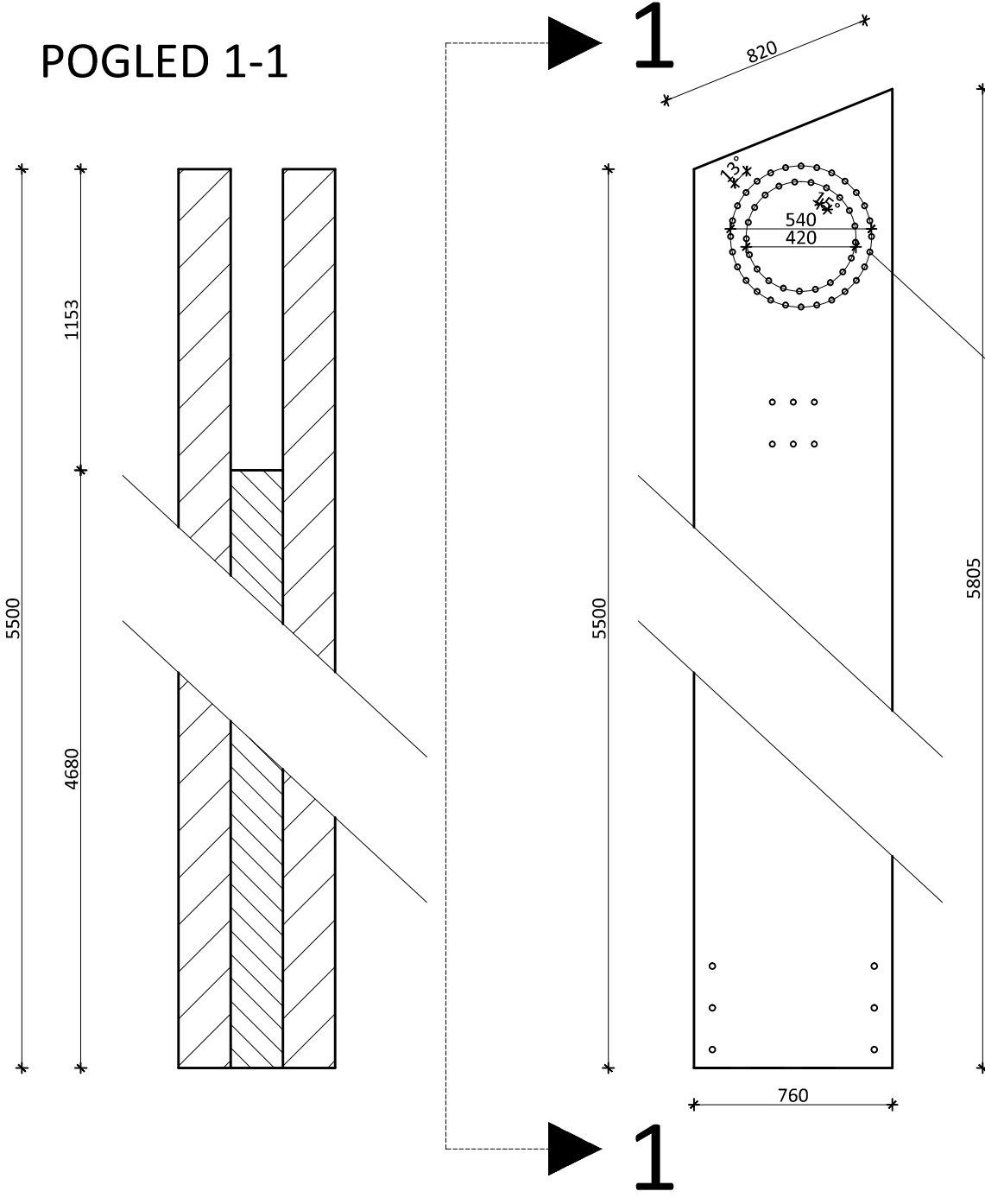


Poprečni presjek

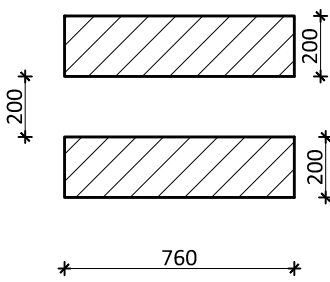


S-STUP GLAVNOG OKVIRA M 1:25

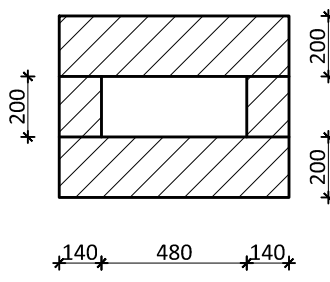
POGLED 1-1



-Poprečni presjek na vrhu stupa:

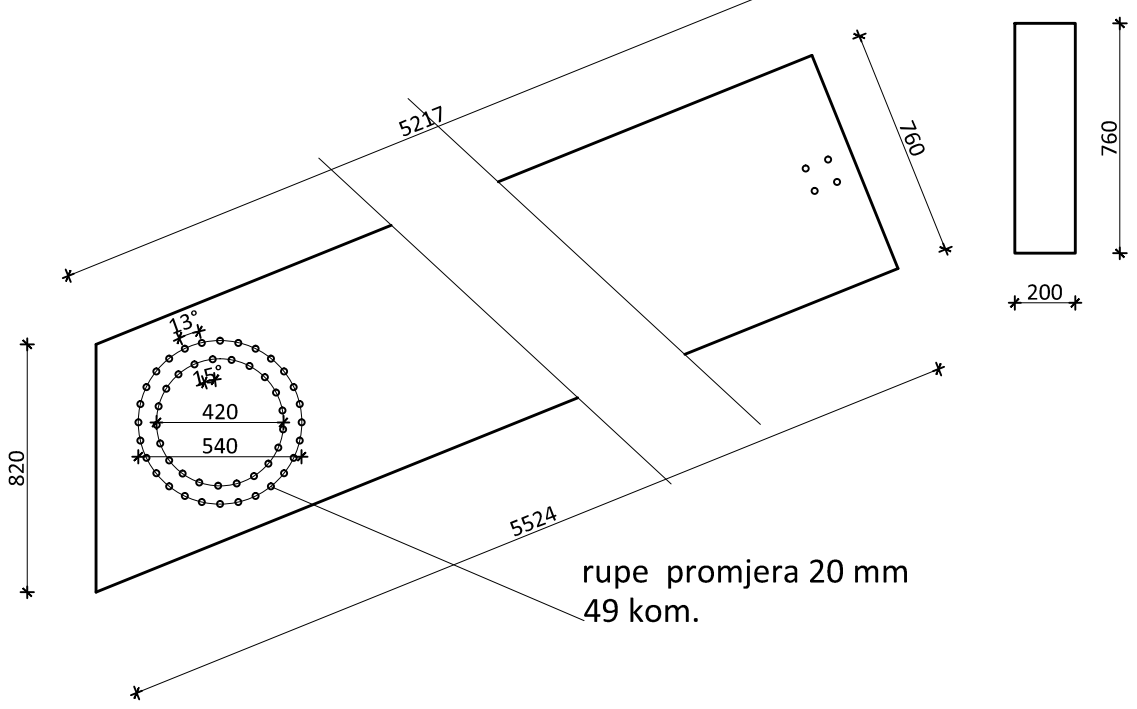


-Poprečni presjek na dnu stupa:



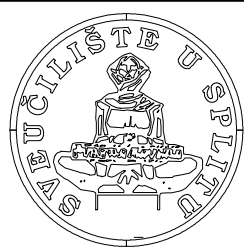
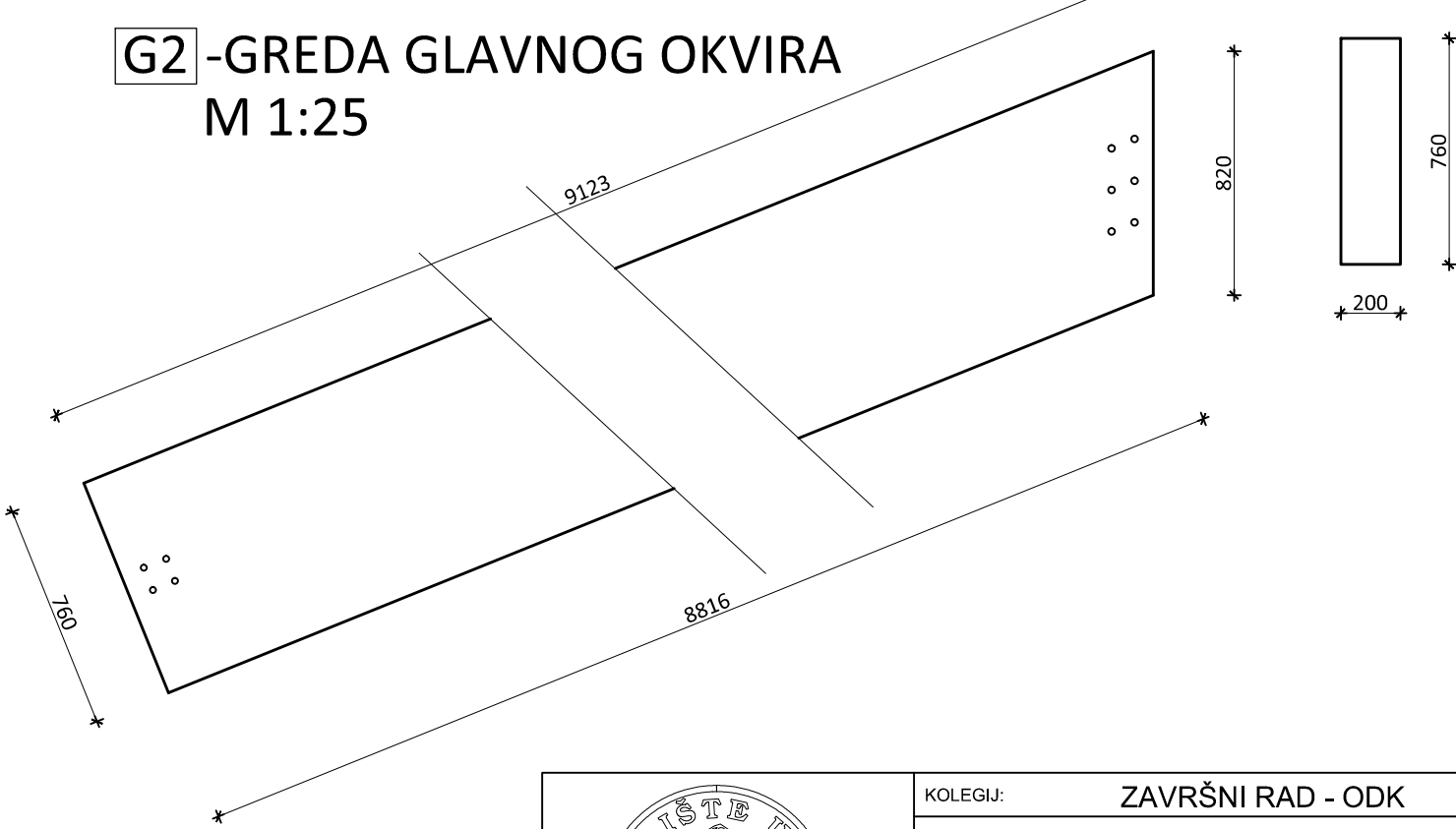
G1 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek



G2 -GREDA GLAVNOG OKVIRA M 1:25

Poprečni presjek



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KOLEGIJ: ZAVRŠNI RAD - ODK	
PROGRAM: KONSTRUKCIJA DRVENE HALE	
STUDENT: NIKICA KRALJEVIĆ, 4347	
SADRŽAJ: ISKAZ MATERIJALA	MJERILO: 1:50
DATUM: RUJAN 2018.	PRIOLOG: 8



## **8. LITERATURA**

A. Bjelanović, V. Rajčić: DRVENE KONSTRUKCIJE PREMA EUROPSKIM  
NORMAMA

doc. dr. sc. Neno Torić: ODK-predavanja, vježbe i rješeni zadaci